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Colorado Plant Diseases

BY
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Assistant in Botany

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Colorado Plant Diseases

By JULIAN G. LEACH
Assistant in Botany

INTRODUCTION

Few people realize the extent of the loss caused by plant diseases. The casual observer is often unaware of the presence of disease in his fields. Furthermore, when the disease is known to be present the damage is usually underestimated. The United States Department of Agriculture, as a result of a nation-wide survey, estimated that in 1917 there was a loss of 64,344,000 bushels of wheat due to disease. This loss amounted to nearly ten per cent of our total production for the year. In the same year, which was not an especially serious one, the potato crop was reduced 117,174,000 bushels, or a little more than one-fourth of the entire crop. The corn crop suffered a loss of 175,344,000 bushels. Other farm crops were reduced in similar proportions. In Colorado alone the injury to farm crops from plant diseases amounted to nearly $10,000,000.

These figures are sufficient to convince anyone that every person who is in any way interested in crop production should be able to recognize the diseases that cause such an enormous loss and should know how to successfully combat them.

The purpose of this bulletin is to furnish to the people of Colorado such information as will enable them to understand the nature of plant diseases, to recognize them as they occur in the field, garden or orchard, and to apply the best and most effective control measures.

For convenience, the bulletin has been arranged in three parts. Part I gives, in simple, non-technical language, something of the nature of plant diseases and the agencies which produce them. Part II deals with specific diseases of Colorado crop plants. The crops have been arranged alphabetically and the diseases of each are treated in order of their relative importance. A few diseases are described which do not occur in Colorado, but on account of their serious nature and the importance of keeping them out of the state it has been thought advisable to include them at this time. Part III treats of the general principles of plant disease control and gives rules and formulae for the preparation and application of standard sprays and solutions for seed treatment.

A bibliography has been added for the convenience of those who may desire further information concerning the diseases described.

PART I

THE NATURE OF PLANT DISEASES

Every plant disease has a cause, although the cause may, in some cases, be rather obscure. The cause may be merely some unfavorable condition of environment such as too much or too little water, excessive heat or cold, or the lack of some essential element in the soil. Most of the important plant diseases, however, are caused by very small microscopic plants which live upon and draw all their food from the diseased plant. These small microscopic plants

Mistletoe Growing on a Western Yellow Pine

live on the large crop plants just as the crop plants live on the soil in which we plant them. They live on the larger crop plants and draw their food from them just as the well known mistletoe lives on and draws its food from the trees on which it lives. They also produce "seed" or spores, similar to the seed of higher plants, which, when they fall upon the proper plant, under the proper conditions, will germinate and penetrate the leaf, stem or root of the plant just as the seed of a higher plant penetrates the soil.

A plant living upon another in this manner is known as a parasite. The plant on which the parasite lives is said to be diseased. A disease caused by such a parasite is known as a parasitic disease.

Diseases, then, can be divided into three general classes on a basis of their cause. Those diseases caused by one organism living upon another are put in one group and called **parasitic diseases.** Those caused by unfavorable conditions of environment such as heat, moisture and food are placed in a second group and called **physiological or non-parasitic diseases.** As mentioned above there are a few diseases the causes of which are not understood. These constitute a third group, which may be called **diseases of uncertain cause.**

PARASITIC DISEASES

The parasites which live upon the crop plants are very numerous and of many kinds. There are almost as many kinds of parasites as there are plants on which they live. For convenience in study, those parasites which cause plant diseases are divided into five groups, those which are very much alike being placed in the same group. These groups have been named as follows: 1. Bacteria, 2. Slime molds, 3. Fungi, 4. Flowering plants, 5. Insects and other animals.

Bacteria—Bacteria are sometimes spoken of as germs or microbes. They are, however, very small plants, extremely simple in form and structure. They are indeed the smallest and simplest plants known. In size they range from 1/50,000 to 1/10,000 of an inch in diameter. In shape they may be spherical (ball shaped), cylindrical (rod shaped) or spiral (shaped like a corkscrew). Those that cause plant diseases are mostly rod shaped. The other kind live on dead organic matter or as parasites on animals.

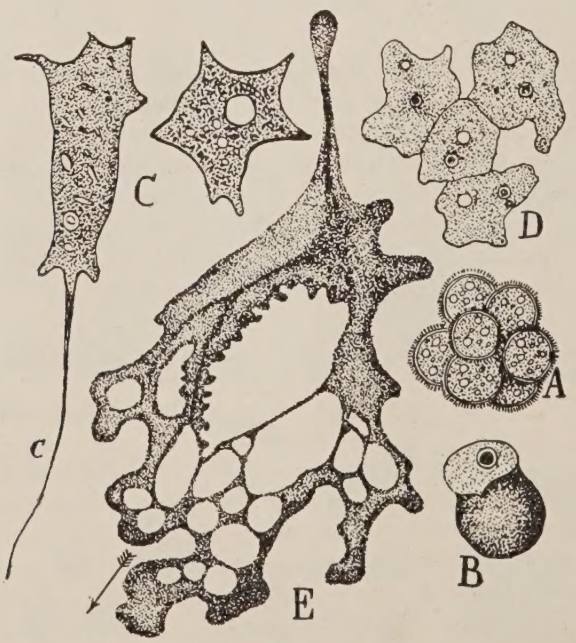
Some common forms of bacteria, greatly magnified. From Transeaus Science of Plant Life. Copyright 1919, by World Book Co., Yonkers-on-Hudson, New York

Some forms of bacteria are able to move about in water and plant juices by means of little hair-like attachments to their body. These hair-like attachments, known as **flagella,** move rapidly back and forth, propelling the bacterium through the liquid. These forms which are capable of motion are the ones which commonly cause plant diseases. Other forms do not have the power of motion and depend on outside agencies such as wind and moving water to carry them from place to place.

Bacteria gain entrance into the leaves, stems and roots of plants by means of breathing pores or injuries. After gaining entrance the bacteria live on the substance of the plant, either killing it (or parts of it) or causing it to make abnormal growth, thus bringing about a diseased condition.

Fire blight of apples and pears, stem blight of alfalfa, wilt of squashes and melons, black rot of cabbage and crown gall of many plants are a few of the serious diseases caused by bacteria.

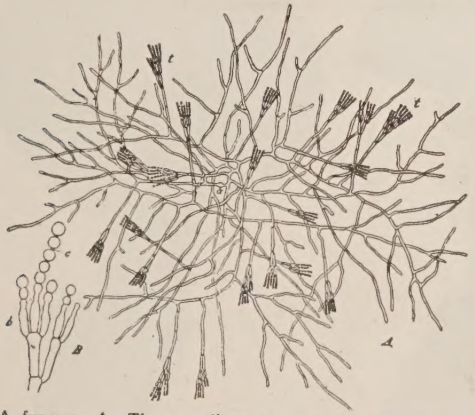
Slime Molds—Another group of plants which sometimes cause plant diseases are the slime molds (Myxomycetes). They are called



The life history of a typical slime mold. A—A group of amebae fusing to form a plasmodium. E—A plasmodium. (After Curtis, Henry Holt & Company.)

slime molds because of their slimy appearance in one stage of their life history. Slime molds are also very small and primitive plants although much larger than bacteria. At one stage in their development they have the appearance of a slimy particle of jelly-like substance. This structure is known as a plasmodium. A plasmodium has the ability to move about by a peculiar rolling or flowing movement. When it grows old or meets with unfavorable conditions the plasmodium breaks up into numerous spores which can live over unfavorable conditions. When conditions are again favorable the spores germinate to form bodies (**amoebae**) similar to a plasmodium but much smaller. A plasmodium is formed by a number of these amoebae uniting with one another to form a single body.

Only a few of the slime molds cause plant diseases. Most of the forms live on dead and decaying wood. A few forms, however, may gain entrance into the roots or stems of plants and cause a disease. Powdery scab of potatoes and club root of cabbage are the most important diseases caused by slime molds.



A fungus. A—The mycelium of a bread-mold fungus. (Penicillium) a—The original spore from which the mycelium grew. t—A tuft of spores. B—A more highly magnified spore tuft, showing how the spores are borne. (After Zopf.)

Fungi — The fungi make up a large and varied group of plants and are responsible for about 90% of the common plant diseases. In addition to those fungi which cause plant diseases there are thousands of other kinds which spend their entire life on decaying plants and other dead organic matter.

Most plants manufacture their own carbohydrate or starchy food by means of the green coloring matter (**chlorophyll**) found in their leaves. The fungi, however, as well as the bacteria and slime molds do not have green coloring matter and consequently can not make their own food. Since these organisms require carbohydrates for their nourishment it is evident that they must obtain it from some source in an already manufactured condition.

Some fungi obtain their nourishment from decaying organic matter, while others obtain it directly from the living chlorophyll

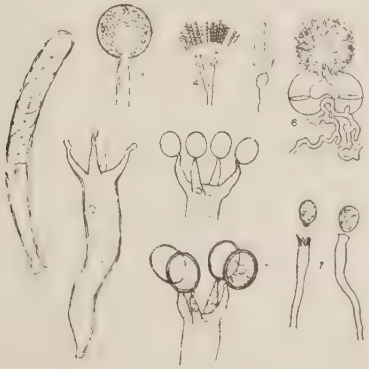
bearing plants. It is the latter kind, of course, which cause plant diseases. Fungi which obtain their food from dead organic matter are known as **saprophytes.** Those which obtain their food from living plants are known as **parasites.**

Fungi differ from higher plants also in that they do not have leaves, stems or roots. The body of a fungus consists chiefly of a fine, branched, thread-like structure, known as a **mycelium.** This branched, thread-like mycelium is usually more or less interwoven to form a cottony or woolly mass such as is seen in the common bread mold fungus. In some kinds of fungi this mycelium may be so crowded together so as to form a solid mass. The common mushrooms are examples of this type of fungus.

A common mushroom. (Original, bulletin 201, by Longyear.)

All fungi reproduce by means of very small seed-like bodies known as **spores.** These spores may vary greatly in size and structure but they all have the power of germinating and forming a new plant. Spores also vary greatly in the way they are produced. The form of the spores and the way in which they are produced are important as means of distinguishing the different kinds of fungi.

In order to thoroughly understand the nature of a plant disease it is necessary to know something of the nature of the organism that produces it. It is, therefore, important that we learn something of the nature of fungi before we take up the study of the diseases which they produce.



Some different kind of fungous spores. (After de Bary, Sachs and Brefield.)

A germinating fungous spore.

Fungi, for convenience of study, are divided into four large groups, the members of each group having a number of important characteristics in common. These groups are known by the following names: 1. Phycomycetes, 2. Ascomycetes, 3. Basidiomycetes, 4. Fungi Imperfecti.

Spores of a Phycomycete. a—A mature sporangium. b—The same sporangium breaking open to free the motile Zoospores. c—Zoospores. (After de Bary.)

The Phycomycetes include the simplest and most poorly developed forms of fungi. In some species hardly any mycelium is developed and the plant is extremely simple in structure. The mycelium never has any cross walls but consists of a continuous tube filled with a jelly-like substance (protoplasm). The mycelium of all other groups is divided into short cells by means of cross walls.

Nearly all the members of this group are water loving and grow best in very moist situations. For this reason a peculiar kind of spore which has the power of swimming about in water is commonly

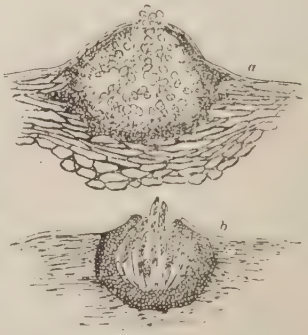
Typical sporangia of the Phycomycetes. a—A sporangium before opening to free the spores. b—Zoospores escaping from the sporangium. Highly magnified. (After de Bary.)

formed. These motile spores are called **swarm spores** or **zoospores.** They swim about for a short while, then come to rest, round up and germinate as an ordinary spore. Swarm spores are commonly formed in a sack-like enlargement of the mycelium or **sporangium.** Swarm spores have a very thin wall or covering and cannot survive any unfavorable conditions. Other kinds of spores are produced, however, which can resist very severe conditions and thus enable the fungi to live over winter and through periods of drought. These resistant or resting spores are usually formed by a sexual process (the fusion of two sexual cells, a male and female **gamete**) and are known as **oospores.** Oospores usually have a thick wall which, after living over the winter, breaks open to set free a number of zoospores similar to those formed in a sporangium.

Such serious diseases as potato wart, late blight of potato and the many downy mildews are caused by fungi of this group.

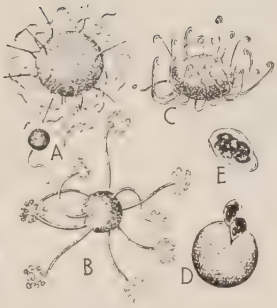
The formation of sexual spores in a Phycomycete. A—Young oogonium, o, and antheridium, n. B—Antheridium fertilizing oogonium. C—Fertilization completed. (After de Bary.)

Asexual spores (conidiospores) of an Ascomycete. (After Tulasne.)



Two spore cases of an Ascomycete in a cross section. a—Asexual spore case (pycnidium). b—Sexual spore case (perithecium). (After Duggar.)

Typical spore bearing organs of an Ascomycete; two asci, each bearing eight ascospores. (After de Bary.)

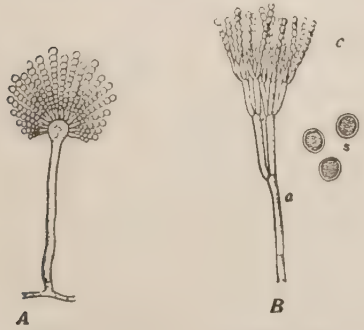


Several forms of spore cases (perithecia) of an Ascomycete. (After Curtis.)

The Ascomycetes are distinguished from all other fungi by the fact that every member of the group has some of its spores (those formed by a sexual process) formed inside of characteristic sacs known as **asci.** The asci always contain a definite number of spores (ascospores), usually eight. The asci are borne in special spore cases. These spore cases are cup-shaped in some forms and spherical or ball-shaped in others.

In addition to ascospores several other kinds of spores may be formed. These are usually without a sexual process and have a variety of forms. Some are borne free on the mycelium and are known as **conidiospores** or **conidia.** The mycelium on which conidia are borne are sometimes grouped together in the tissue of a plant, forming a compact mass and giving rise to a structure known as a pustule or **acervulus.**

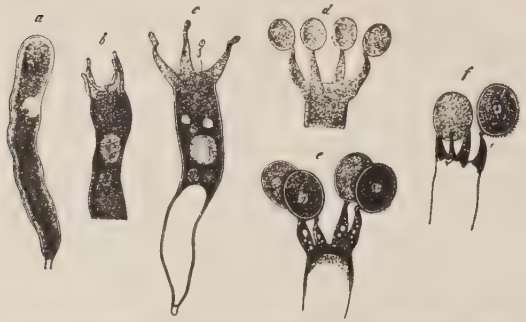
Other spores are borne in spherical or flask-shaped spore cases or **pycnidia.** Spores borne in a pycnidium are called **pycnospores.**



Asexual spores of two Ascomycetes. A—Aspergillus. B—Penicillium (A. after King; B. after Longyear.)

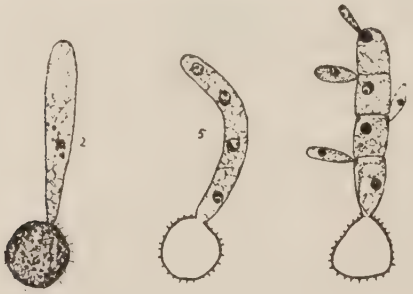
The Ascomycetes are not as dependent upon water as the Phycomycetes and never form zoospores. They make up the largest group of fungi and a great many of them are plant parasites. Peach leaf curl, plum pocket, brown rot of peaches, ergot of rye, leaf spot of alfalfa and the powdery mildews of many crops are some of the numerous diseases caused by fungi of this group.

The Basidiomycetes do not form their spores in sacs but bear them externally on more or less club-shaped stalks or **basidia.** Each basidium usually bears four spores. Spores born on basidia are spoken of as **basidiospores** or sometimes **sporidia.** The typical basidium is often modified into a short, usually four-celled tube, arising directly from a germinating spore. This modified basidium or **promycelium** is found in the rusts and smuts.

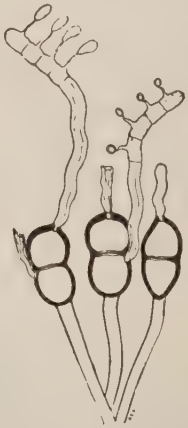


Spore formation in Basidiomycetes. The successive stages of development are in order of letters. (After de Bary.)

The Basidiomycetes also constitute a large group and include, in addition to the rusts and smuts, which are serious plant parasites, most of the common mushrooms.



Germination of a smut spore showing a modified basidium. (After Harper.)

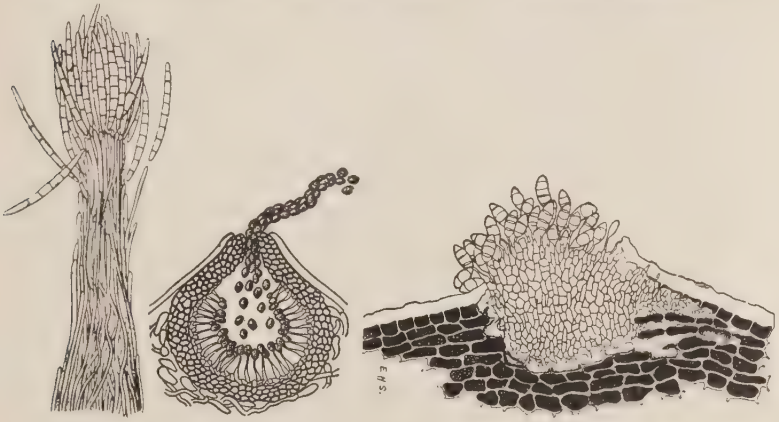


Germination of spores of asparagus rust showing a modified basidium. (After Smith.)

The Fungi Imperfecti, commonly spoken of as the imperfect fungi, constitute a group of miscellaneous individuals which do not form the type of spores that would identify them with either of the preceding groups. As their name indicates they are imperfect in that no sexual spores are formed. The spores which are formed closely resemble the asexual spores of the ascomycetes and it is

very probable that if the sexual spores were known they could be transferred to the Ascomycete group. In fact, the sexual spores have been discovered for many species of this group and as a result they have been transferred to their proper place among the Ascomycetes. The spores of the imperfect fungi as mentioned above are formed much as the asexual spores of the Ascomycetes.

Flowering Plants—In addition to the bacteria, slime molds, and fungi there are a few higher plants wich draw their nourishment from other living plants and are therefore parasites. Mistletoe and



Three methods of spore formation in the imperfect fungi.
a—Sporodochium c—Pycnidium. b—Acervulus
(a. after Tulasne; c. after Quaintance and Shear; b. after Smith.)

dodder are the most common parasitic flowering plants. They obtain their food by sending root like structures **(haustoria)** into the tissues of the plant on which they are living and absorbing the already manufactured food.

Insects and Other Animals—Many important and serious plant diseases are caused by insects, mites and other animals. This field, however, is best left to the Entomologist. Diseases produced by such organisms are not included in this bulletin.

NON-PARASITIC DISEASES

Among the agencies responsible for physiological or non-parasitic diseases may be mentioned **unfavorable chemical and physical conditions of the soil, unfavorable climatic conditions and mechanical injuries.**

Unfavorable chemical conditions of the soil may be the result of either a deficiency or an excess of some element. The absence of

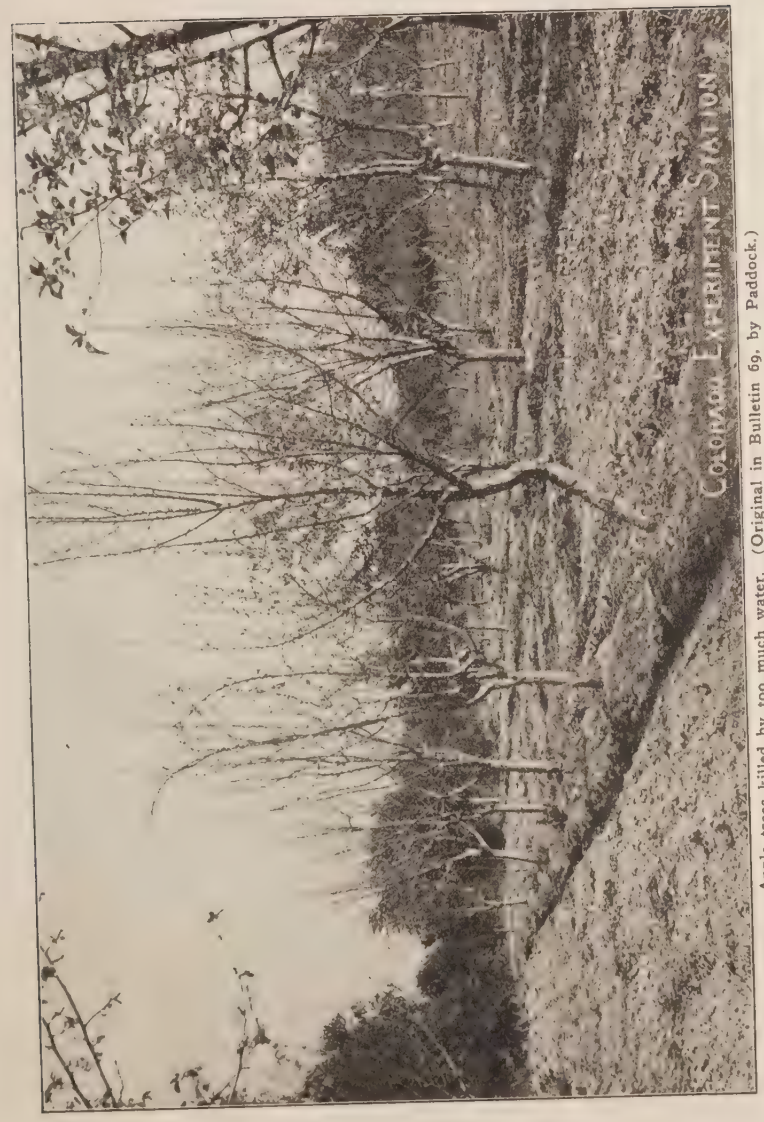
potassium in the soil causes a dwarfing of plants and interferes with the manufacture of starch by the leaves. A deficiency of magnesium, iron, or nitrogen also reduces the amount of starch production in leaves. Too much nitrogen in the soil is said to make a plant more susceptible to frost injury.

Excessive quantities of nitrates in the soil are extremely injurious to plants. Certain Colorado soils have the power of fixing atmospheric nitrogen and this fixation often proceeds to the point where cultivated plants are completely killed over a localized area. Truck gardens, alfalfa, oat, barley and sugar beet fields often develop barren patches on which nothing will grow. Equally serious is the damage done to apple and cherry orchards in which many trees are completely killed. Often an entire orchard will be lost from this cause.

This excessive fixation of nitrogen is due to the activity of certain bacteria which live in the soil. These organisms take free nitrogen from the air and change it into the form of nitrates. The nitrates are dissolved in the soil water and as a result of evaporation become concentrated near the surface of the soil. This trouble is spoken of as "Nitre Injury."

The physical condition of the soil also has much influence on the health of plants. A heavy clay soil that packs easily is often injurious to plants. A course sandy soil often will not hold sufficient water for the plant growth. A lack of water will cause a plant to wilt or die. Too much water prevents air from reaching the roots of plants and brings about an unthrifty condition.

A nitre spot. (Original in Colorado Experiment Station Bulletin 155, by Headden.)



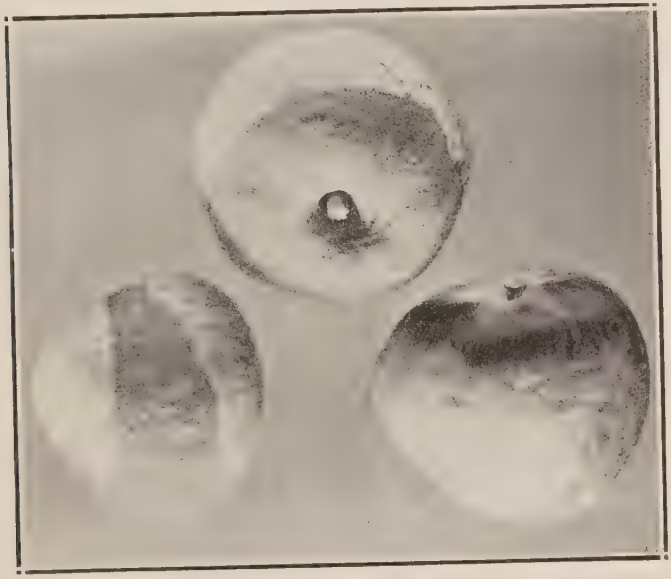
Apple trees killed by too much water. (Original in Bulletin 69, by Paddock.)

Injury due to unfavorable soil conditions. (Original in Bulletin 69, by Paddock.)

Unfavorable climatic conditions may often seriously injure plants. Very strong sunlight produces a condition known as sunscald. Too much shade interferes with the manufacture of starch by the leaves.

Frost injury and freezing are common among plants. In addition to the direct injury from frost or freezing such a condition often makes a plant more susceptible to certain parasitic diseases. For example, the bacterial stem blight of alfalfa develops extensively only after the alfalfa plants have been injured by frost. The bacteria gain entrance to the plant tissues through the cracks produced as a result of freezing.

The weight of ice and snow often breaks off the limbs of trees and thus opens the way for parasitic fungi. The fall of hail stones



Frost injury on apples.

is a source of much damage to all forms of crops. Strong winds often are the cause of much damage. Limbs and buds are broken from trees; corn and small grain are sometimes blown down when the wind is accompanied by heavy rain. Heavy rains often injure the blossoms and prevent the pollination of fruit trees. Lightning injury is common although not of very great importance.

Smoke and gases from smelter and manufacturing plants have

been shown to be injurious to plants of all kinds for many miles around. Trees and shrubs in the larger cities are often injured by smoke.

Mechanical injuries may be produced in a variety of ways. Fruit trees may be injured by cultivating too closely. Trees as well as herbaceous plants are frequently injured by hail. Young fruit trees are often barked by rodents or other animals. The opportunities offered for the entrance of parasitic fungi by mechanical injury are perhaps more important than any direct result of the injury.

Orchard fruits are often injured and disfigured by excessive and improper application of chemical sprays or by the application of sprays of too great concentration.

DISEASES OF UNCERTAIN CAUSE

Certain plants are subject to a disease commonly known as "mosaic" the cause of which is doubtful. The disease, as the name indicates, is characterized by a mottling or mosaic condition of the leaves of an affected plant. No parasitic organism large enough to be detected with a miscroscope can be found associated with the disease, yet the disease in some cases has been shown to be highly infectious. If the juice from a diseased leaf is injected into a healthy plant this plant will become diseased after a period of eight or ten days. This leaf juice or virus can be passed through the finest filter and yet retain its power of infection. For this reason the diseases are commonly said to be due to a filterable virus.

The Irish potato is subject to certain diseases known as curly dwarf, leaf roll and degeneracy, the causes of which are not thoroughly understood. The diseases are all characterized by a dwarfed condition of the plant and a low yield of tubers. Attempts to establish definite symptoms for each disease as well as experiments to determine their cause have been more or less confusing. The Plant Pathologists of the country, however, have gotten together and a concerted effort is being made to solve this important problem. Curly-top of sugar beets and peach yellows are other diseases, the causes of which are somewhat obscure.

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M.A.Palmer

PART II

DISEASES AFFECTING COLORADO CROP PLANTS

On account of the fact that no adequate survey of the plant diseases of the state has ever been made, the distribution, prevalence and severity of many of the diseases in Colorado are not known with any great degree of accuracy. Limited observations on the part of the writer and the fragmentary reports that have been received from time to time are the only sources of information available at present.

A survey of plant diseases in Colorado has been started, however, in co-operation with the office of Plant Disease Survey, of the United States Department of Agriculture, and it is hoped that within the next few years much valuable data will be collected on this subject.

In the following discussion no attempt has been made to treat all the diseases that occur on crop plants in Colorado. Only those known to be of considerable economic importance have been described. On the other hand a few diseases are included that have not yet been found in the state but which, on account of their serious nature and the liability of their introduction, it was thought best to mention at this time.

The crops are arranged alphabetically and the diseases of each are treated in somewhat the order of their relative importance. The figure in parentheses just following the name of the disease refers to a bulletin, which gives a more complete discussion of the trouble. The list of bulletins will be found at the back of this publication.

ALFALFA

Bacterial Blight (Pseudomonas medicaginis) (1)—This is one of the most serious diseases of alfalfa in Colorado, and is widely distributed over the southern half of the state.

Affected plants are stunted and lighter green in color than normal. Infection is chiefly on the stems. In early stages the stem has a watery semi-transparent, yellowish to olive green appearance along one side. A sticky amber liquid oozes from diseased tissue and soon dries to form a shiny cast which becomes black with age. Where the ooze collects in drops, light amber colored scales are formed. Affected leaves are water soaked and pale yellow in color.

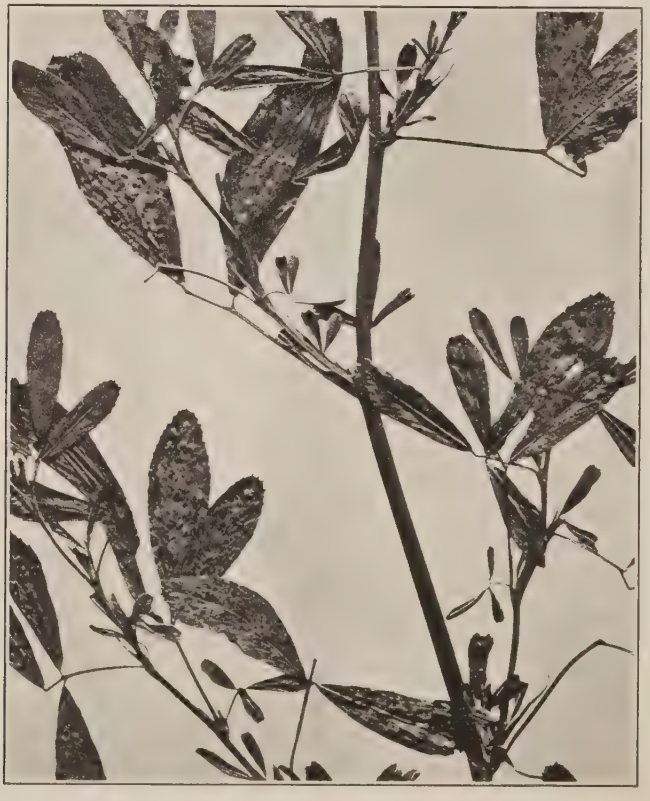
Colored Plate on opposite page shows the bacterial blight of alfalfa. Original was used in Bulletin 158, by Sackett.

They soon wilt, die and become dry and brittle. In one-year-old plants the disease may extend into the crown and roots and killing the entire plant.

The disease is caused by a bacterium which gains entrance into the plant through cracks caused by frost injury. For this reason the disease commonly affects only the first crop of alfalfa. It is most severe after late spring frosts.

Frosted alfalfa should be clipped as soon as danger of further injury from frost is past. This rids the plant of the cracked stems by means of which the bacteria enter and permit the production of new healthy shoots.

Leaf Spot (Pseudopezizza medicaginis) (2)—Leaf-spot is the most common and perhaps the most destructive of alfalfa diseases. It is widely distributed, occurring where ever alfalfa is grown.



Leaf-spot of alfalfa. (Original in Bulletin 212 by Robbins.)

Small brown or black spots are formed on the leaves. They are first evident on the upper surfaces. The spots are often very numerous, causing the leaves to drop off.

Leaf-spot is caused by a fungus. The black spots are the cup-shaped spore cases bearing a large number of spores. These spores live over the winter on dead leaves and are scattered about to the new leaves the following spring.

No practical control measures are known. The disease is considered as one of the necessary evils of alfalfa culture. Early cutting of heavily infected fields may reduce the loss of leaves.

Yellow-Leafblotch (Pyrenopezizza medicaginis)—This disease is similar in many respects to leaf spot. It is not as common, however, and has been known to occur in this country only since 1914. In certain localities where it is abundant it is said to produce a large loss of hay. Its distribution in Colorado is not known.

In appearance it differs from the leaf spot chiefly in that the spots are smaller and grouped together in large yellow blotches. The affected leaves become water soaked during rains and later shrivel and fall.

Yellow-leafblotch is produced by a fungus very similar to the one causing leaf spot and is almost as difficult to control. Careful mowing so as to leave no stray plants along fence rows and irrigation ditches will probably reduce the amount of the disease.

Downy Mildew (Peronospora trifoliorum)—Downy mildew is very injurious in certain localities under favorable conditions. It was first noticed in Colorado in 1906 when it was confined to a few localities. It has since spread over practically the entire state.

Only the leaves are affected. Light green or yellow green spots and blotches are produced. A gray downy growth appears on the under side of the affected leaves which changes to purple with age. The first crop seems to be more heavily infected than the succeeding ones.

The gray downy growth on the leaves is a mass of fungus growth bearing thousands of small egg shaped spores. These spores break open in drops of rain or dew, setting free a number of swarm spores, which swim about in the water for a while, then germinate and penetrate the leaves, producing a new disease spot.

Effective control measures are not known. Since the spores require lots of moisture for germination excessive irrigation should be avoided.

Dodder (Cuscuta spp.) (3)—Dodder is a common alfalfa parasite. It is widely distributed over the state although it is most prevalent in southern Colorado. Its injury is usually confined to relatively small tracts of alfalfa. These affected spots are covered with a tangled mat of yellow threads that twine closely around the plant. Affected plants are greatly stunted and are often killed.

The dodder plant is a true seed plant and has small white flowers. The dodder seed germinates in the soil and begins its growth just as any other plant but when it comes into contact with

Dodder on alfalfa; an enlarged drawing to show method of attachment (after Longyear).

the alfalfa plant it twines itself about the stem, sends little root-like structures **(haustoria)** into the alfalfa stems and robs the plant of its food. As soon as it has established itself on the alfalfa plant it loses its connection with the soil and lives entirely upon the alfalfa.

When affected areas are small, infected plants should be cut close to the ground beginning at the outside of the area and working inward; then burn the plants when dry and watch for any renewed growth.

If affected areas are extensive mow the entire crop closely, allow the hay to dry and then burn it. Plow the field and keep in cultivated crops for several years.

Dodder seed resemble alfalfa seed and are often found mixed with them. It is often spread and introduced into new areas in this way. Samples of all alfalfa seed should be sent to the Colorado seed laboratory for examination before planting.

APPLE

Fire Blight (Bacillus amylovorus) (4), (5), (6)—This is the same disease that affects pears. It does nearly as much damage on the

Fire blight. An infected apple showing the drops of ooze containing countless numbers of bacteria. (Original in Colorado Experiment Station Bulletin 84, by Paddock.)

apple as on the pear. For a discussion of the disease see Pear.

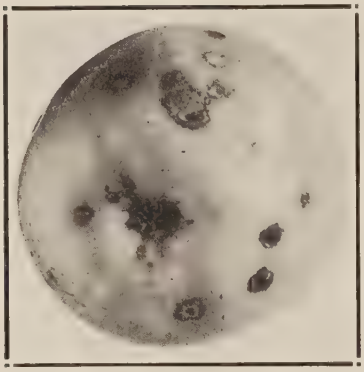
Scab (Ventura inaequalis) (7)—Scab is one of the most serious diseases of the apple in the eastern states. It has been observed in Colorado in slight quantities for the past three years. It will in all probability become more prevalent as time goes by.

The disease affects leaves, flowers and fruit. On the leaves it makes its first appearance on the lower side as irregular olive-brown velvety spots. Later, spots more regular in outline appear which are on the upper surface of the leaves. On the fruit the spots are at first small, brown and smooth but later they become cracked and rough. Several small spots may grow together forming large scabby areas. When the attack is severe the fruit shrivels and falls.

Fire blight. A hold over canker in which the bacteria live over the winter. Small drops of a sticky liquid containing large numbers of bacteria ooze from such cankers in the spring. (Original in Colorado Experiment Station Bulletin 177, by Sackett.)

Apple scab on leaves

The fungus causing scab lives over the winter on the dead



Apple scab on fruit

leaves. Spores from these leaves infect young leaves and fruit in the spring. These form a new crop of spores and spread the disease from place to place.

Scab can be controlled by spraying with lime sulfur, one gallon of concentrated solution (testing 32 degrees Baume) to forty gallons of water. To this should be added two pounds of arsenate of lead to fifty gallons of diluted spray. Applications should be made as follows: (1) Just before the flower buds open. (2) Just after the petals fall. (3) Two weeks after the second spray. In dry seasons the latter spray may not be necessary.

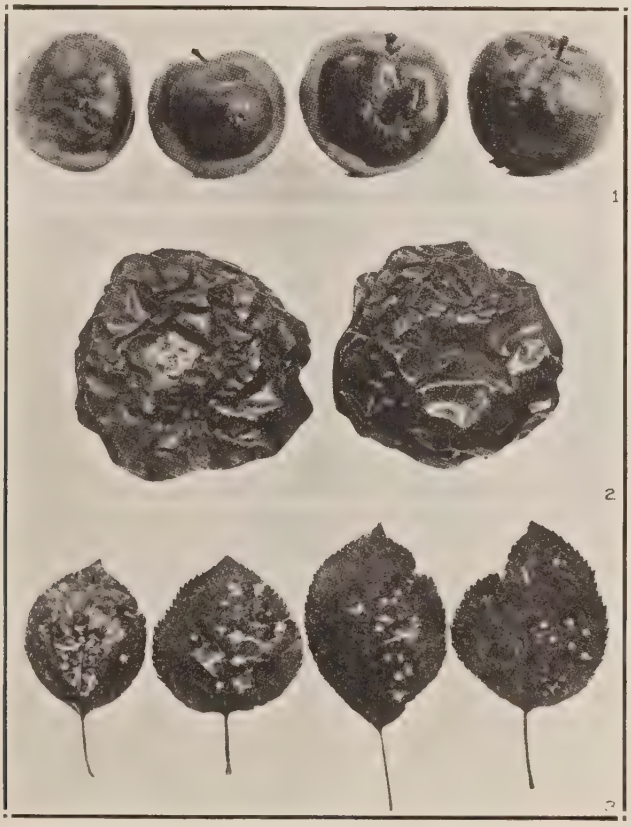
Experiments made in New York state have demonstrated that scab may be controlled by the application of a mixture of powdered sulfur and arsenate of lead. Applications must be made with a special dusting machine from both sides of the trees using one and one-half to two and one-half pounds of the mixtures per tree. Make at least three applications at the times recommended for the spray and in rainy seasons a third or fourth should be applied.

Black Rot (Physalospora cydonia) (8)—Black rot occurs more or less throughout the state. The disease affects the fruit, twigs and leaves. The fruit is attacked usually when nearly mature, decaying rapidly and becoming brown at first but later turning black. The apples remain firm for some time but eventually dry and shrivel up. Just beneath the skin little flask shaped fruiting bodies **(pycnidia)** are formed. Many thousands of spores are formed in these, which are pushed out through a small opening at the top and scattered about by the wind and rain to infect other fruits and twigs.

On the twigs the disease produces first a discoloration of the bark. The discolored area spreads gradually until the twig is girdled and it often spreads to the larger branches producing a rough canker. Large branches may also be attacked directly through cracks and wounds.

On the leaves brownish circular spots are formed which lead to premature shedding of the foliage.

Black rot may be controlled by carefully cutting out all infected branches and spraying with (4-4-50) Bordeaux mixture. The first spray should be applied about the middle of July and should be



Black rot of apple. 1—Early stages of infection on fruit. 2—Later stage on fruit. 3—On leaves. (After Hesler.)

followed by a second application about two weeks later. The lime sulfur spray recommended for control of scab may be substituted for Bordeaux mixture if applied sufficiently late in the season. Bordeaux mixture, however, is said to be more effective.

Bitter Rot (Glomerella cingulata) (9), (10)—The distribution

and severity of this disease in the state are not known. It is, however, one of the most serious diseases of the apple in the eastern states and will very probably become of greater importance in Colorado.

Bitter rot attacks the fruit and twigs but is not known to occur on the leaves. It begins on the fruit as small light brown spots which rapidly enlarge finally involving the entire fruit. Small black spots soon appear on the surface of the larger spots. These are the fruiting bodies **(pycnidia)** of the fungus and soon break through the epidermis and free their spores in small pink masses. These spores are scattered about by wind and rain, causing secondary

Bitter rot of apple. (After Garman.)

infection. Cankers are developed on the twigs, small limbs and fruit spurs. Large branches are seldom affected. The dead bark is cracked and roughened.

The lime sulfur spray is not effective for bitter rot. All infected twigs should be carefully cut out and Bordeaux (4-4-50) should be applied just before the buds open and again two or three weeks later.

Powdery Mildew (Podosphaera leucotricha) (12)—Nursery stock where ever apples are grown suffer more or less from powdery mildew. Both leaves and twigs are affected but the fruit is seldom injured.

A white or grayish powder is produced on the leaves; more often on

Powdery mildew on apple leaves

the under side. The twigs may be entirely covered with the same powdery growth. This powdery substance is made up of millions of small white spores **(conidia)** produced by the fungus which is growing over the surface of the leaf. These spores when blown from leaf to leaf germinate and produce new infections. In the late summer another form of spore is formed in small spherical spore cases **(perithecia)**. When the perithecia are formed they change the white grayish spots to dark smoky patches. The spores borne in perithecia on account of the protection afforded by the spore case are able to live over the winter. They are set free in the spring by the breaking open of the walls of the perithecia, and are scattered to healthy plants where they start the disease anew.

Powdery mildew is a difficult disease to control. All infected leaves and twigs should be cut out and destroyed. Ordinary lime-sulfur spray, to which has been added three pounds of iron-sulfate, has proven effective in some sections of the country. The spray should be applied first just after the petals have fallen and this should be followed by two additional applications at intervals of two or three weeks.

Crown Gall (Pseudomonas tumefaciens) (13)—Crown gall is most injurious in the nursery. The disease is characterized by large rough galls, occurring most commonly at the ground line. Galls are formed most frequently where root grafts are carelessly made. The galls

may be either hard or soft. In some instances instead of galls large bunches of small fibrous roots are formed. This gives rise to the name "hairy root" which is sometimes applied to the disease.

Crown gall is caused by bacteria which live in the tissues of the plant stimulating it to abnormal growth. The same bacteria may cause galls on many other plants besides the apple.

Plant only disease free nursery stock and destroy all infected plants. Avoid injuring the roots in any way. In grafting care should be taken to use root and scion of approximately the same size. Most states have horticultural inspectors who inspect all nurseries at least once a year, and condemn all infected stock. This greatly aids in controlling the disease.

Nitre Injury (14), (15)—As stated in Part I of this bulletin, certain Colorado soils have the power of fixing atmospheric nitrogen in excessive quantities. The accumulation of large quantities of nitrates in the soil in this way is extremely injurious to many plants. The apple is extremely susceptible to nitre injury.

The leaves of affected trees have a characteristic appearance. A burning and drying begins at the tip and progresses rapidly along the margin and finally involves the entire trees and even whole orchards are completely killed. The process is a rapid one, whole trees being killed in a period of three weeks. Injury frequently follows irrigation. The water of irrigation brings the nitrates into solution, the condition in which they are the most injurious.

It has been shown that clean cultivation tends to hasten the accumulation of nitrates. Plowing under of cover crops is said to be an effective means of checking the formation of nitrates. This not only retards the accumulation of nitrates but vegetable matter, which is needed by the soil of most orchards, is added.

Good drainage is also an important factor in preventing nitre injury. Well drained soil will often take off sufficient nitrates in solution to prevent excessive accumulation.

Experiments have shown that soils containing large amounts of nitre and on which nothing will grow, can be reclaimed by flooding. Flooding is accomplished by preparing the ground in the usual manner for sowing grain. The area to be flooded is surrounded with an embankment of earth and water is led into the enclosure so that the entire piece of ground is covered to a depth of several inches. As the water seeps into the soil and drains off more water should be supplied keeping the surface covered for ten days. In this

Apple leaves showing nitre injury. Note the characteristic browning along margins. (Original in Colorado Experiment Station Bulletin 155, by Headden.)

way the accumulated nitrates are dissolved and washed out. Ground treated in this way should produce good crops.

Apple Rot, Blue Mold (Penicillium expansum)—Blue mold is a destructive rot of ripe apples occurring most commonly in storage. Apples rotting from this cause give off a characteristic foul odor. The rotted area is soft and bright brown in color and spreads rapidly until the entire fruit is decayed. Under very moist conditions bluish tufts of spores are formed over the surface of the diseased fruit.

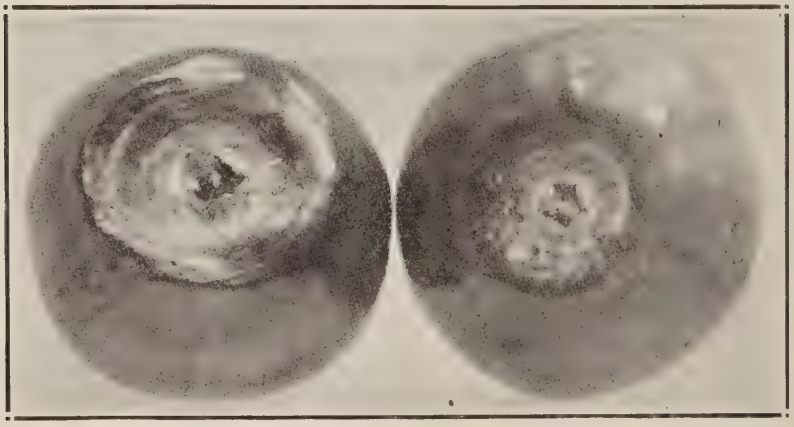
The decay is caused by a fungus which gains entrance through bruises or other mechanical wounds. In controlling the rot it is therefore important to prevent the skin of the apple from becoming injured in any way. One rotten apple in the barrel furnishes spores

that are ready to enter any such wound on a healthy apple, so it is advisable to eliminate all apples showing the slightest sign of decay before putting the fruit in storage.

If the apples are fancy stock and it is desired to keep them a long time, it will probably pay to wrap each apple in a piece of clean paper.

Since apples decay more rapidly at high temperatures it is well to store them in cool dry places.

Black Mold (Alternaria sp.) (16)—A fruit rot which attacks the blossom end of ripe apples is common in Colorado and is often the source of much loss. The affected fruits show a dark brown sunken area at the base of the shriveled flower parts. The spots



Apples affected with black mold. (Original in Bulletin 212, by Robbins.)

may be scarcely noticeable at time of harvest but they increase in size in storage until the entire apple is ruined. Cars of fruit which were apparently in perfect condition when shipped have shown as high as ten to twenty per cent of infected apples on reaching their destination. The Winesap seems to be particularly susceptible. A similar trouble has also been noted on Kieffer pears.

No extensive experiments have been made to determine methods of control, but it is very probable that if a fungicide spray was applied according to the plan recommended for other apple diseases, the loss would likely be reduced.

Frost Injury—(17), (18)—Injury from low temperatures is an important factor in apple growing. Frost injury may occur during

the winter months or it may be due to late spring frosts. Injury occurring during the winter months is sometimes spoken of as winter injury.

All parts of the trees may be affected. Twigs, portions of large branches and roots are often killed by severe cold during the winter months. Late spring frosts usually injure leaves, fruit, buds, and blossoms. Affected leaves crimp and curl and "frost blisters" are often formed. Young fruits may be entirely killed or may be only slightly injured giving rise to the peculiar russeting or "frost band." To prevent frost injury do not irrigate or cultivate late in the fall. Allow the trees to thoroughly mature before cold weather. Do not apply nitrogenous fertilizers except in early spring.

Spray Injury (19), (20)—Apple leaves and fruit are sometimes injured by improperly applying sprays or by applying sprays improperly prepared. Injured fruits show characteristic russet blotches. Leaf injury is in the form of irregular scattered light brown spots. If the spray is very strong holes may be burned into the leaves.

To avoid spray injury: (1) Follow carefully directions for the preparation of a spray mixture. Do not get it too strong. (2) Use pure chemicals. (3) Use a good nozzle and apply spray under high pressure in order to obtain a fine mist. (4) Be sure that the spray is thoroughly mixed.

NEGLECTED ORCHARDS

Throughout Colorado there are many orchards which are suffering from the lack of attention. No orchard can be expected to yield profit without a reasonable amount of care. Many orchards have never had a spray applied. Improper cultural practices, careless pruning and general neglect all go to produce the most favorable conditions for the growth and development of all fungus and insect diseases.

After large sums of money have been spent in establishing an orchard it is poor business not to give it proper care and make it yield its maximum production. Many orchards in Colorado that are not now paying interest on the investment could be made profitable by a little intelligent orchard management including judical use of sprays.

APRICOT

Black Knot (Plowrightia morbosa) (21)—see Plum. **Brown Rot (Sclerotinia cinerea)** (22), (23)—see Peach. **Fruit Spot (Coryneum beyerinckii)** (24), (25)—see Peach. **Scab (Cladosporium carpophi-**

lum) (26)—see Peach. **Crown-Gall (Pseudomonas tumefaciens)** (13)—see Apple. **Frost Injury** (17)—see Apple.

ASPARAGUS

Rust (Puccinia asparagi) (27), (28), (29), (30)—Asparagus rust was introduced into this country from Europe about twenty-five years ago. It spread rapidly over the entire country within a very few years and seriously threatened the asparagus crop where ever it appeared.

Rust affects the tall branching plants that spring up after the cutting season in spring and summer. Numerous oblong orange red spots are found on the stems and leaf-like branches. These spots are pustules containing thousands of yellowish brown spores which are blown about by the wind to healthy plants. Whenever one of

Asparagus rust. Summer stage. Asparagus rust. Winter stage.

these spores fall on an asparagus plant under the proper conditions of moisture and temperature it germinates and penetrates the plant forming a new pustule of spores. These may be produced in such abundance that the whole plant will take on a yellowish appearance and spores will be blown in clouds for some distance by the wind.

The rust saps the nourishment from the plant and hinders it in its food making process. As a result of this the underground stems do not receive the normal amount of stored material, consequently they fail to send up a good crop of "spears" the following year.

The red or summer spores are short lived and cannot live over the winter. In September and October a crop of hardy black spores

are formed on the stems of the plant. The black spores live over the winter and germinate in the spring just in time to infect the young plants. In controlling asparagus rust, therefore, it is necessary to destroy by burning all diseased stalks. Asparagus often escapes from cultivation and grows along fence rows. Unless these stray plants are destroyed they will serve as sources of early spring infection.

Dusting with dry flowers of sulfur has been recommended for the control of this rust in California. The best grade of flowers of sulfur should be used. The first application should be made at the rate of 150 pounds per acre about three weeks after the last cutting of sprouts. This should be followed by a second application at the rate of 100 pounds per acre one month later. The sulfur should be applied in a fine dust preferably in the early morning while the plants are wet with dew.

Bordeaux mixture (5-5-50) to which has been added a resin mixture is also said to be effective. The resin mixture which should be added to the Bordeaux mixture is made as follows: resin, 5 gallons; potash lye, 1 pound; fish oil, 1 pint; and water, 5 gallons. Two gallons of this mixture diluted to ten gallons should be added to forty gallons of Bordeaux spray. A variety of asparagus known as Palmetto is said to be resistant to rust.

BEAN

Bacteriosis (Pseudomonas phaseoli) (31), (32), (33)—Bacteriosis or Bacterial Blight is one of the most serious diseases of the bean in Colorado. It attacks the stems, leaves, pods and seeds of both field and garden beans. Watery amber yellow spots ranging in size from tiny specks to areas of one-half inch in diameter are produced on the pods. The spots are irregular in outline and often have a red margin. If a spot occurs just over a seed within the pod the disease is likely to penetrate entirely through the pod and affect the seed.

The spots formed on the stems and leaves are very similar, at first, to those on the pod but rapidly turn brown, becoming dry and brittle. If the disease is severe the plants will shed their leaves and fail to mature seed.

Bacteriosis as the name implies is produced by bacteria which enter the plant through its breathing pores or wounds produced by mechanical injury. The organism lives over the winter on diseased seed.

Hand pick disease-free seed from healthy plants. Plant the seed

Bacteriosis of bean. (Original in Bulletin 226, by Kezer and Sackett.)

thus selected in a seed plot of ground that has never grown beans before. Use the seed from this plot to plant the larger fields. Seed for the seed plot must be selected in the field for diseased seed cannot be detected as they come from the thrasher.

Where ever practical all diseased vines should be destroyed by burning. Avoid cultivating beans when they are wet with dew or rain.

Anthracnose (Colletotrichum lindemuthianum) (31), (34), (35) —Anthracnose of bean only recently made its appearance in Colorado. In 1918 it was very prevalent and did much damage. In 1919, due perhaps to the very dry season, it was of little importance.

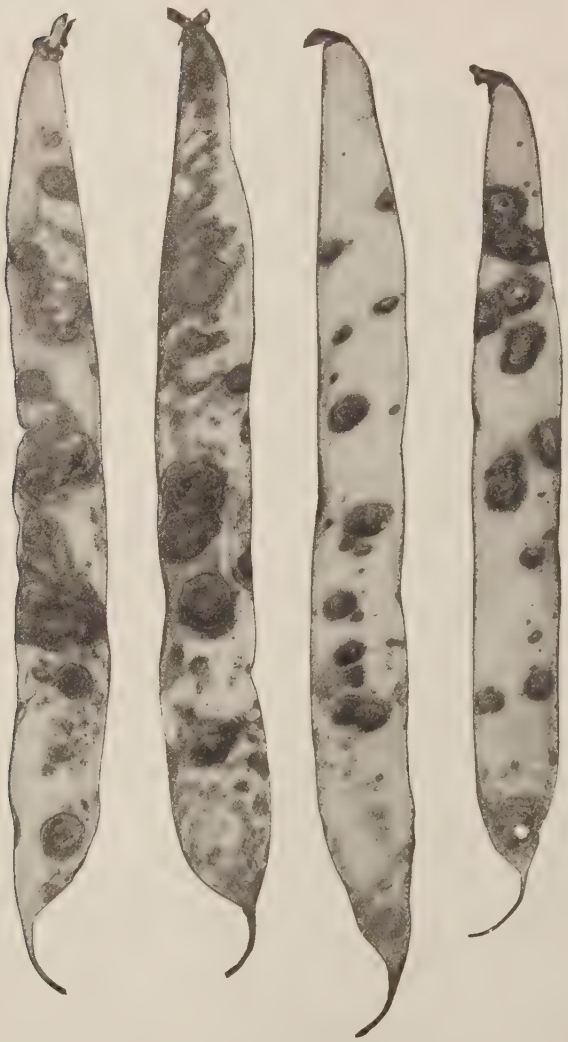
The disease is first noticed on the seed, leaves and stem of young plants. Dark reddish brown spots are produced on the stems and larger veins on the under side of the leaves. Reddish-brown circular, sunken spots are formed on the pods. The fungus works its way from these spots through the pod and into the seed. Seed infected in this way carry the fungus over from year to year.

The spores of the fungus produced in the center of the reddish brown spots are glued together by a sticky material, which is dissolved as soon as a drop of moisture touches it. Any disturbance of the plant while wet with dew or rain would tend therefore to spread the disease. For this reason beans should never be cultivated while they are wet from rain or dew.

Since the disease is carried over by diseased seed the same process of seed selection recommended for control of bacteriosis is applicable to the control of anthracnose.

Certain varieties of beans are said to be more resistant to anthracnose than others but recent work indicates that there are two or more specialized forms of the fungus causing anthracnose and that a variety may be resistant to one form but very susceptible to another. This is a question that should be further investigated. If different specialized forms of the fungus exist it is very important to know how many there are and where they occur.

Stem Blight (Rhizoctonia sp.)—Beans throughout the state were seriously injured the past year by a fungus which attacked the stem just beneath the surface of the ground. Brick-red to dark brown irregular lesions were produced which often girdled the entire stem. These interfered with the transportation of food and greatly reduced the vigor of the plants. In many cases the injury was sufficient to kill the entire plant. The fungus causing the injury was not



Anthracnose of bean. (After Whetzel.)

definitely determined but is in all probability a species of the common soil fungus, Rhizoctonia.

A crop rotation, growing beans on the same soil not oftener than once in three years seems to be the only practical method of reducing the loss from this trouble. The disease is one that should be thoroughly investigated.

Rust of bean. (Original in Bulletin 226, by Kezer and Sackett.)

Rust (Uromyces appendiculatus) (36)—Bean rust is common in Colorado although it usually appears too late in the season to do much damage. In favorable years, however, it may appear sufficiently early to be rather destructive.

Small, raised, rusty-red, powdery spots are formed on the leaves commonly on the lower surface. These spots are pustules containing thousands of small reddish-brown spores which are scattered by wind and rain to healthy plants where they germinate and cause more spots. The disease interferes with the food making processes of the plants and decreases its vitality. Late in the season the reddish-brown spores are replaced by black ones which are sufficiently hardy to live over the winter. The disease is a difficult one to control. Since the black spores, formed on the leaves, carry the fungus over winter the destruction of affected vines should tend to lessen the amount of disease.

Certain varieties are said to be more resistant than others, but the question is one that needs further investigation.

Sunscald—A non-parasitic disease greatly resembling bacteriosis is common in Colorado. The brownish spots and streaks which resemble so closely the bacterial spots are the result of burning or scalding by strong sunlight. Sunscald is not of much economic importance as it produces no appreciable reduction in yield.

BEET

Root Rot (Rhizoctonia sp.)—Both garden and sugar beets are subject to root rot. The disease first becomes evident by a drooping and wilting of the leaves. On examination the outer leaves are seen to be rotted at the base. This decay soon spreads into the crown and root causing the infected area to turn brown. Cracks often appear and in severe cases the entire beet may be destroyed.

Moist weather and excessive irrigation favor the development of the disease. The fungus causing the disease lives from year to year in the soil. Careful irrigation and crop rotation are the most practical means of reducing the loss from root rot.

Curly Top (38), (39)—Curly top is one of the most destructive diseases of the sugar beet, especially in the western beet fields. It is characterized by an inward curling of the leaves, checked growth and the production of an abundance of hairy roots.

Curly top is produced by the bite of the sugar beet leaf hopper (Eutettix tenella). The bite of the insect is not sufficient to produce the disease, but the insect carries within its system some substance

Rhizoctonia root-rot of sugar beet.

Curly dwarf of sugar beet. (After Townsend.)

which when injected into the plant brings about the diseased condition. The insect gets this substance into its system by biting a diseased beet. A leaf hopper which has never been upon a diseased plant may bite a healthy beet without producing the disease, but if it is on a diseased beet before it bites a healthy one the disease will follow.

It has recently been shown that a number of other plants including a few common weeds may also be affected with curly top. A leaf hopper from such a plant may carry the disease to healthy beets. It is probably in this way that the disease lives over the winter. Curly Top is a difficult disease to control. The destruction of the leaf hopper would probably reduce the amount of curly top but this is not very practical.

Cercospora leaf spot of beet.
(After Townsend.)

Leaf-Spot (Cercospora beticola) (40)—This leaf-spot affects both garden beets and sugar beets although it is much more injurious on the latter. It is common where ever beets are grown and is often the cause of much loss in the yield of sugar beets in Colorado.

The spots first appear on the outer leaves as small brown dots often with a purple margin. As the spots increase in size usually reaching one-eighth to one-fourth inch in diameter, the centers become ashen gray due to the formation of thousands of spores of the fungus. As soon as the spores are formed they may be scattered about by wind and rain and irrigation water to healthy leaves causing new spots to form where ever they fall. The spots may become very numerous affecting the leaf stalk as well as the blade. Badly affected leaves become brown and dry. The destruction of outer leaves and the formation of new ones in the center often causes the crown to become considerably elongated.

Spraying with Bordeaux (4-5-50) is said to be effective though somewhat impracticable. It has recently been shown that the first infection in spring may come from infected seed and that plants raised from seed treated with a formaldehyde solution (15 parts to 1,000 for seven minutes) attain a better development and are more productive than those grown from untreated seed.

The most common source of infection however is the old beet top material left on the ground after the preceding harvest. Removal of infected beet tops or deep plowing to cover up all such refuse will greatly reduce the amount of the disease.

Beets should not be planted on the same soil oftener than once in three years and such rotated fields should be separated from unrotated fields by at least one hundred yards.

Leaf-Spot (Phoma betae)—A leaf spot differing from the one described above is common on sugar beets throughout the state

although it never grows as serious. The spots characterizing the injury produced by **Phoma betae** are light brown in color and from a quarter to one-half inch in diameter. Numerous small black specks, often arranged in concentric rings are found scattered over the surface of the spots. These black specks are the small flask shaped spore cases **(pycnidia)** of the fungus. The spores escape from these pycnidia and are scattered to healthy leaves where new spots are formed. The same control measures recommended for the control of Cercospora leaf spot apply to Phoma leaf spot.

A crown rot of mature beets and a damping off of young beets are caused by this same fungus.

Nematodes* **(Heterodera schachtii and Heterodera radicicola)** (37)—Nematodes, or eel worms as they are sometimes called, are very small eel-like worms that live in the soil and feed upon the roots of various plants. There are two nematodes attacking sugar beets in Colorado, the sugar-beet nematode and the root-knot nematode. Both species, so far as known, occur on river bottom lands more commonly than on uplands. The damage caused by them is greatest on light, sandy soil. This is due to the fact that the nematodes thrive better in such soil.

The effect upon sugar beets is two-fold. The yield is very greatly lowered and the sugar content of the crop reduced. In severe cases the young beets are killed and the stand destroyed.

Control measures consist of (1) preventing the spread of the nematodes, (2) preventing their multiplication.

1. Nematodes are spread: By waste water from infested fields; on implements used in working infested land; by being carried from infested fields to uninfested ones on the feet of animals and persons working them; by feeding beet tops from infested fields and applying the manure produced to uninfested land.

2. The multiplication of nematodes is checked by rotation of crops. Small grain, with the exception of oats, may be used where land is infested with sugar beet nematodes. Corn, cabbage, turnips, oats, and beans should not be planted on infested land.

Where the root-knot nematodes occur any of the small grains or corn may be planted. Potatoes, cabbage, tomatoes, and other vegetables or root crops should not be grown.

BLACKBERRY

Anthracnose (Plectodiscella veneta) (41), (42), (43)—see Raspberry. **Leaf-Spot (Septoric rubi)**—see Raspberry.

*Thanks are due to Mr. Asa C. Maxson of the Great Western Sugar Company for the information on this disease in Colorado.

CABBAGE

Black-Rot (Pseudomonas campestris) (44)—Black-rot at present is not a serious disease in Colorado. In some sections of the United States it is one of the most destructive of cabbage diseases. Black-rot makes its first appearance along the edges of the outer leaves. Affected areas wilt, turn yellow and dry up. The veins of the leaf become blackened. The disease spreads along the veins until it reaches the main stem from where it rapidly spreads to all parts of the plant producing the characteristic black rot. Frequently a plant may be affected one one side only in which case the affected side appears dwarfed. Much loss is often suffered in storage when slightly infected plants are stored. Infection may occur in seedling stage, killing the entire plant in a very short time.

Black rot is a bacterial disease. The bacteria may gain entrance to the plant through breathing pores or mechanical injuries, but they enter more commonly through the water pores along the margin of the leaves. The organism lives over the winter in the soil and decayed cabbage refuse and also on seed from diseased plants.

Since infection may take place in the seed bed the plants should be closely watched to see that no infected plants are taken to the field. Crop rotation is necessary for effective control. Seed should be disinfected by soaking in corrosive sublimate solution (1-1000) for fifteen minutes or in formaldehyde (1-200) for twenty minutes.

Black-Leg (Phoma lignam) (44)—Black-leg is one of the most destructive of cabbage diseases. Often the greater portion of the crop may be destroyed.

The disease is first noticed as irregular sunken spots with a purplish border on the stems near the surface of the ground. The spots increase in size until the stem is completely girdled. The plant is, of course, weakened and ultimately dies. Small black dots then appear all over the surface of the diseased tissue. These are the spore cases or pycnidia containing the thousands of spores which are set free to affect new plants.

Crop rotation and destruction of all infected plants are the most reliable control measures. Seed from diseased fields should never be planted unless thoroughly disinfected with corrosive sublimate. Seed should be planted in beds containing soil that has never grown cabbage before.

Yellows (Fusarium conglutinans) (45)—The prevalence of this disease in Colorado is not known. It is one of the most important in the states further east.

Affected plants, as the name indicates, are characterized by the yellow color of their outer leaves. The plants are stunted and the lower leaves show a tendency to drop at the slightest touch. Young seedlings are often affected in which case the plant rapidly wilts, turns black and dies.

Cabbage yellows is due to a fungus that lives from year to year in the soil, gaining entrance to the roots and checking the flow of water from the roots to the rest of the plant. Crop rotation and the use of resistant varieties are the most practical means of controlling the disease. The Wisconsin Agricultural Experiment Station has had remarkable success in selecting strains of cabbage resistant to yellows.

Club-Root (Plasmodiophora brassicae) (46)—Club-root is not common in Colorado. In the eastern states, however, it is a very destructive disease. The roots of infected plants become much enlarged and swollen, each infected root taking on a peculiar spindle shape. A dwarfing of the remainder of the plant results. In warm, dry weather infected plants wilt sooner than healthy ones. In severe cases the plant may die. Club-root is due to infection by a slime mold which gains entrance into the roots from the soil. The little slimy masses of protoplasm, that make up the body of the organism, work their way from cell to cell in the root, stimulating it to abnormal growth. Late in the season these masses of protoplasm inside the root break up into small round spores. When the root decays these spores are set free in the soil. Under proper conditions these spores germinate to form new masses of protoplasm which may affect new cabbage plants.

Since the organism causing club-root lives in the soil, crop rotation is one of the best control methods. All roots of infected plants should be destroyed. A heavy application of lime (100 bushels per acre) every few years is said to be an effective means of control.

CELERY

Late Blight (Septoria petroselini var. apii) (47)—This is by far the most serious disease of celery in Colorado. Few fields are free from the trouble and many are seriously damaged.

Both leaves and stems are affected. Small light brown spots are first formed on the lower outer leaves. The spots later turn black and if the leaf is badly affected it will dry up and die. Many small black spore cases **(pycnidia)** are found over the surface of the spots and imbedded in the leaf. Many small but long needle-shaped spores are set free from a round opening in the tops of the pycnidia.

The spores are scattered to healthy plants by wind and rain and irrigation water where they germinate to produce new spots.

On the stems the spots are similar to those on the leaves often occurring in clusters, uniting to form larger spots which may cover the greater portion of the stem. Such infected stalks soon turn brown and soft, finally dying and drying up.

Late blight can be controlled by spraying with Bordeaux mixture (5-6-50). The first spray should be applied to the seed bed at the rate of thirty gallons per acre. If the disease is prevalent it would be advisable to spray the seed bed at least twice. After the

Late blight of celery. (After Coons and Levin.)

plants are transplanted to the field, spraying should begin at the first appearance of blight. Spray once a month thereafter until the danger is past. In the field 50 to 100 gallons to the acre should be applied according to the size of the plants. Effective control depends upon the thoroughness with which the spraying is done.

Early Blight (Cercospora apii)—This is also a leaf-spot disease but is not as serious as the late blight. Large irregular dead spots are formed on the leaves earlier in the season. On account of the slight losses from early blight spraying is not considered profitable.

Root-Rot (Rhizoctonia sp.)—Celery is often destroyed by a root rotting fungus which attacks the root at an early stage of development, causing them to decay with a moist soft rot.

Crop rotation and the avoidance of over irrigation tend to reduce the amount of the trouble.

CEREALS

The diseases affecting the various cereals are more or less similar and therefore are discussed as a group.

Smuts (40), (48), (50), (51)—The smuts of cereals are perhaps the most destructive of all plant diseases. They were responsible for a loss of nearly 135,000,000 bushels of grain in the United States in 1917. The loss in Colorado alone was almost 2,000,000 bushels.

The smut affecting one kind of plant is so specialized that it cannot grow on any other species of plant. Each cereal has its own smut or smuts which can affect that cereal and no other.

CORN

Corn Smut (Ustilage zeae)—There is only one smut of importance affecting corn. It is very common in Colorado and is the source of much loss.

Corn smut.

Large black smut masses are formed on any part of the corn plant above ground including ears, stems, leaves, and tassels. Millions of spores are contained in these smut masses and are scattered broadcast by the wind. Each of these spores which may live over the winter in the soil, germinates in the spring and forms dozens of still smaller spores that are easily blown about by the wind. These secondary spores may infect any part of the corn plant and cause a new mass of spores.

For obvious reasons seed treatment is not effective in controlling corn smut. It has been shown that smut spores may pass through the digestive tracts of animals uninjured. Furthermore such spores germinate in manure piles which form ideal places for the production of the secondary spores in great quantities. It is plain therefore that smutted corn should be fed to animals and only rotted manure should be placed on corn fields. Since the spores may live in the soil, crop rotation is advisable.

BARLEY

Covered Smut (Ustilago hordei) This is the most common and destructive of the two smuts affecting barley. Fields often contain

as high as 35 or 40 per cent smutted plants. The barley grains are replaced by a mass of black dust-like spores which are the "seed" of the smut fungus. These are scattered about in threshing, some of them alighting on the surface of healthy grains of barley where they remain until the grain is planted. The smut spores germinate at the same time that the grain of barley germinates, and penetrates the tender seedling and grows up through the stem. At fruiting time the smut fungus grows out into the flowers and the developing kernel is replaced with a mass of black smut spores.

Covered smut of barley Loose smut of barley

Since the smut spores live over on the surface of the grain, the logical way to control the disease is to treat the seed with a disinfecting solution that will kill the spores without injurying the grain. A solution of formaldehyde in water has been found effective for this purpose. See directions for seed treatment in Part III.

Loose Smut (Ustilago nuda)—Loose smut is common in Colorado but is not as destructive as covered smut, seldom causing more than 5% loss. Loose smut differs from covered smut in that the spore masses are not enclosed by a membrane but are borne loosely on the stem. Because of this fact the spores are scattered about by the wind as soon as they are formed which is just at the time that normal uninfected plants are blooming. Some of these smut spores fall upon the flowers of the blooming barley and grow directly into the developing grain. The grain hardens and becomes mature, however, before the fungus can form spores. The fungus is thus enclosed in a grain of barley that to all appearances is perfectly normal. When this grain germinates, the fungus also begins to grow and grows up through the stem replacing the developing kernels with a mass of loosely borne spores. Thus we see that the loose smut differs from the covered smut also in the time and manner of infection.

Because of the fact that the loose smut fungus lives over on the inside of the grain rather than on the surface the ordinary formaldehyde treatment is not effective. A complicated hot water treat-

ment is the only known method of killing the fungus within the kernel without injuring the grain.

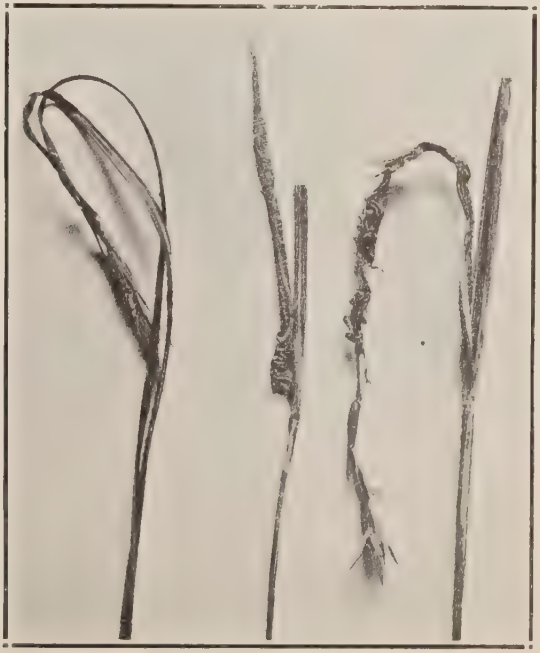
Because of the difficulty in applying the hot water treatment without injuring the seed it is advised that this method be used only for treating a small quantity of grain. The small lot of treated grain should be planted in a seed plot separated as far as possible from other grain fields. The seed from this seed plot should be used in planting the larger fields the succeeding year. The resulting crop should be free of loose smut.

For directions in applying the hot water treatment see Part III.

OATS

Oat Smuts (Ustilago avenae and **levis)**—There are two smuts of oats, a loose smut and a covered smut, but they differ so slightly that for all practical purposes they may be considered as one. Both are extremely destructive. The life history of the oat smuts is practically the same as that of the covered smut of barley and therefore the formaldehyde treatment is effective.

Smut of oats. A—Covered smut. B—Loose smut.



Flag smut of rye. (After Stakman and Levine.)

RYE

Flag Smut (Urocystis occulta) (52)—This is the only smut affecting rye. Masses are formed on the leaves and stems as well as the kernels. Affected plants are usually stunted and seldom produce normal heads. On the leaves long gray blisters are first formed which on breaking open expose a mass of black spores. Similar blisters are found on the stems often causing them to become twisted and curved. If heads are produced they are nearly always empty or else the kernels have been replaced by masses of smut spores.

The spores may live over either on the surface of healthy rye kernels or in the soil. The formaldehyde seed treatment together with crop rotation is effective in controlling rye smut.

SORGHUM

Kernel smut of sorghum.

Under the name sorghum are included milo, kaffir, feterita, durra, broom corn, sudan grass and shallu.

Kernel Smut (Sphacelotheca sorghi)—This is the most common smut of sorghum. As the name indicates the kernels alone are affected, each kernel becoming a mass of smut spores. The head retains its usual shape and form. The spores live over on the surface of normal seed and infect the plant as soon as the seed germinates. The formaldehyde treatment is effective. Milo is resistant to all smuts.

Head Smut (Sorosporium reilianum)—Head smut is not common in Colorado. The entire heads of infected plants become a large deformed mass of smut spores. Head smut differs from kernel smut in that the spores are not necessarily carried with the seed but is wind distributed affecting the plant either from the soil or above ground. Seed treatment therefore is not effective. Milo is resistant to head smut as well as to kernel smut.

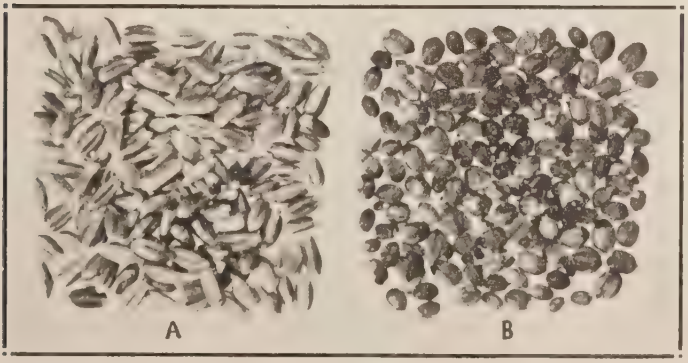
WHEAT

Bunt or covered smut of wheat.

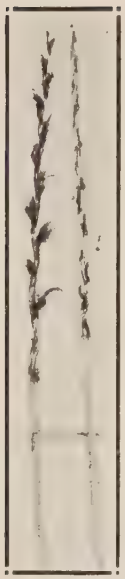
Covered Smut or Bunt (Tilletia laevis and tritici)—Covered smut is the most destructive of the smuts affecting wheat. It is estimated that this smut was responsible for a loss of 21,971,000 bushels of wheat in the United States in 1917.

The kernels alone are affected, each kernel being transformed into hard smut balls retaining somewhat the shape of the normal grain. Smutted grains, however, are usually darker in color, lighter in weight and more round in shape. A smutted kernel when crushed breaks up into a mass of black spores and gives off a characteristic foul odor resembling the smell of decayed fish.

The spores are carried over on the surface of the kernels and infect the germinating seedling. The formaldehyde seed treatment is therefore effective.



A—Healthy wheat kernels. B—Bunted wheat kernels.



Loose smut of wheat.

Loose Smut (Ustilago tritici)—Loose smut of wheat is identical in all respects to loose smut of barley described above with the exception that it can affect only wheat, while the loose smut of barley can affect only barley. The hot water treatment only will control loose smut.

Flag Smut (Urocystis tritici) (53)—A flag smut of wheat very similar to flag smut of rye has recently been discovered in this country. Previous to this it was known to occur only in Australia, Japan and India. It has been found in the United States only in one place, namely, Madison county, Illinois.

The government has established strict quarantines in an effort to prevent the further spread of the disease and the strongest efforts are being made to completely eradicate it. Seed treatment combined with crop rotation as recommended for flag smut of rye should effectively control flag smut of wheat. All seed wheat should be treated before planting as a precaution in preventing its introduction into new areas. Should flag smut of wheat be discovered in Colorado it should be immediately reported to the Agricultural College.

RUSTS

The rusts of cereals are too well known to require much description. In destructiveness they rank second only to the smuts. In some years the loss even exceeds that caused by the smuts. In 1916 it is estimated that the black stem rust alone destroyed at least 280,000,000 bushels of wheat in Canada and the United States. To this must be added the loss of oats, barley, and rye, which ranged from 15 to 25 percent of the crop.

The rusts occur not only on the cultivated cereals but many species of wild grass are also affected. Certain rusts may live also on such plants as the barberry or buckthorn which makes them much harder to control. Each cereal has it own particular rust which will attack no other cereal, but which may affect a number of wild grasses. Each kind of grass may also be attacked by two or three different kinds of rust.

The cereal rusts may be roughly classified into two groups, namely, the leaf rusts that are more commonly found on the leaves and the stem rusts of those found on both stems and leaves. It is the latter group that is responsible for the greatest loss.

Stem Rust of Wheat, Oats, Barley, and Rye (Puccinia graminis)—Each cereal has its own specialized form of stem rust which can affect none of the other cereals. Each form, however, can affect a number of wild grasses. Elongated reddish brown blisters break open and a mass of red rust-colored spores are set free to be blown about by the wind for long distances. When these fall on the proper host under the proper conditions they germinate and produce new rust spots. Later in the season black spores are formed in the rust spots instead of the red spores. These black spores have thick walls and may live over the winter while the red spores have thin walls and survive the winter only in very mild climates. The black spores do not germinate until spring and then can not infect any of the cereals. They do, however, infect the common barberry shrub. On the leaves of the barberry they produce yellowish or orange colored spores. These yellow spores produced on the barberry cannot infect the barberry but are blown back to the cereals and grasses where they again produce the red spores.

Black stem rust of wheat.

The rusts cannot be controlled by any known method of spraying or seed treatment and little success has rewarded efforts to develop resistant varieties. The eradication of the common barberry from which the rust gets its start in the spring gives more promise for success than any other method. Losses from this rust have been successfully avoided in Denmark since 1903 by this measure. The United States Department of Agriculture has underway a campaign to destroy all common barberries in the wheat growing sections of the United States. Many bushes have already been destroyed. Learn to recognize the barberry bush and if you have one on your property destroy it. Write to the Agricultural College for further information.

Leaf Rust of Wheat (Puccinia triticina)—Leaf rust as the name indicates commonly occurs on the leaves and is never as destructive

as the stem rust. In severe cases of infection, however, a considerable reduction in yield may result.

Small round orange-red blisters are formed in which are thousands of red spores. These spread the rust from plant to plant and may live from year to year starting the rust anew each spring. Black spores are also formed by leaf rust but no plant is known in this country that they infect. No effective control measures for this rust are known.

Leaf Rust of Barley (Puccinia simplex)—This rust is very similar to the leaf rust of wheat. No effective control measures are known.

Leaf Rust of Rye (Puccinia dispersa)—There is also no essential difference between this rust and the one described above.

Crown Rust of Oats (Puccinia coronata)—This is a rust somewhat intermediate between the leaf and stem rusts. It is found chiefly on the leaves but may also occur abundantly on the stems. It lives one stage of its life on the buckthorn in the same way that the stem rust lives on the barberry. In oat growing sections where the buckthorn is plentiful its destruction would undoubtedly reduce the amount of this rust.

Yellow Stripe Rust of Wheat, Barley and Rye (Puccinia glumarum)—Yellow stripe rust is found on the above three cereals and a number of wild grasses. It never occurs on oats. It seems to be confined to the western part of the United States although it has been found in a few places in Colorado. It often becomes destructive west of the Rocky Mountains.

Yellow stripe rust as its name indicates is characterized by the bright yellow stripes formed on the leaves of the affected plants. The yellow stripes and blisters are also quite commonly formed on the inside of the glumes and often on the kernel itself. No successful control measures have yet been worked out.

OTHER CEREAL DISEASES

Barley Stripe (Helminthosporium graminium) (57)—Stripe is a serious disease of barley in Colorado. Fields were observed in 1919 in which as high as 25 per cent of the plants were heavily affected.

Diseased plants show long yellowish to brown stripes on the leaves and stems. The heads are also often affected turning a grayish brown and forming shrivelled grain. In several cases the entire plant may die, usually about the heading time. The spores of the

Barley stripe.

fungus are formed on the surface of the stripes and are scattered to the barley kernels in thrashing. They apparently live over the winter on the kernels.

Experiments carried on at the Wisconsin Experiment Station indicate that stripe may be controlled by treating the seed with formaldehyde, one pint to thirty gallons of water for two hours. After treatment the grain should be dried as rapidly as possible and planted at once or stored in bags that have been disinfected with the formaldehyde solution.

Ergot (Claviceps purpurea) (58)—Ergot affects rye, wheat, barley, oats and a number of wild grasses. It is more common, however, on rye and wheat and is not often found on barley and oats.

The kernels of affected plants are replaced by hard black ergot bodies ranging from one-half to an inch or more in length.

Ergot is caused by a fungus which infects the plant while in blossom. The spores fall upon the young ovary, grow into it, replacing the developing kernel with a mass of fungus tissue which becomes the ergot body. The ergot body in the process of development produces spores in great numbers scattered over its surface. These spores are scattered by wind and insects to other flowers and thus spread the disease from plant to plant. When the grain is mature the ergot bodies often fall to the ground where they remain over winter. The following spring when the grain is just beginning to head out the ergot bodies germinate by sending up a number of branches to the surface of the soil, each of which produces a quantity of spores on knob like tips. The spores produced in this way start the first infection in the spring.

Ergot of rye.

Since the ergot bodies live over in the soil, rye should not be planted on the same soil two years in succession. All ergot bodies should be separated from seed grain before planting. This is best accomplished by a process known as "salting." The principle of this process lies in the fact that the ergot bodies are lighter than normal kernels and will float in a solution of salt water in which the normal grain will sink. The grain is poured slowly with constant stirring into a barrel of salt water the strength of which should vary with the particular lot of grain. The ergot bodies are skimmed from the top and destroyed. The solution is then drawn off and the grain washed with water to remove the salt, dried and planted. For more specific directions see Part III.

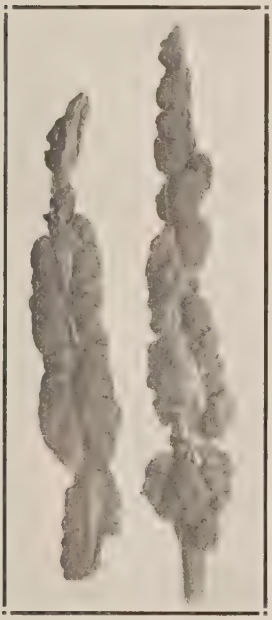
Take-All (53)—A disease of uncertain cause which closely resembles a serious disease of cereals common in Europe and Australia has been recently discovered in the United States. It was found in close association with the flag smut of wheat which fact adds strongly to the evidence that it is the same trouble that is so destructive in the old world. This fact, however, has not yet been definitely established.

In fields but slightly infested small patches of dwarfed plants are found scattered here and there. The plants in these patches if not killed outright take on a characteristic bluish green color. In some fields the infestation may be so severe that practically all the plants are so affected. In such fields many plants are completely killed. The roots become badly rotted and the stems at the surface of the ground turn brown. If affected plants survive early attacks and produce heads no grain is formed and the spikes take on a whitish color. This characteristic gives rise to the name "White head" sometimes applied to the disease.

No effective control measures have yet been worked out. Grain from infested fields should never be used for seed. A rotation keeping any cereals off the land for four or five years should be practiced. Any suspicious cases should be immediately reported to the State Agricultural College.

CHERRY

Black Knot (Plowrightia morbosa) (21)—Black knot is common on cherry and plum trees throughout the state. The disease is confined entirely to the woody part of the tree, causing black swollen wart-like knots extending for several inches along twigs and branches. Affected twigs are often bent and twisted or otherwise deformed. The knots are at first soft and cushion like with a velvety surface but turns black, hard and rough with age.



Black knot of plum. (Original in Bulletin 212, by Robbins.)

The knots are due to a fungus which invades the tissues of the branches causing the abnormal growth. The knots are made up partly of fungus growth and partly of deformed tissues of the twig. In the early stages when the knot is soft and cushion like many small spores **(conidia)** are borne over the surface giving it a velvety appearance. Later when the knot become hard, spore cases are formed imbedded in the surface. These spore cases or perithecia contain spore sacks or asci, each ascus containing eight small ascospores. The ascospores protected by the spore cases may easily live over the winter to start the disease again next spring.

Black knot may be controlled by pruning out and destroying all knots as soon as they appear. Wild plums and cherries are also affected and the disease may spread from these. Where it is not practical to eradicate these, spraying with Bordeaux mixture is advised. One application should be made during late winter and another when the buds begin to swell. Other applications may be made if found necessary.

Shot-Hole (Cylindrosporium padi) (59)—This leaf spot disease affects not only the leaves but also the fruit. On the leaves small brown spots are formed which often drop out giving rise to the characteristic "shot-hole" appearance. Badly affected leaves usually turn yellow and drop. On the fruit the disease causes small reddish-brown spots. The injury from these spots, however, is usually less than that resulting from loss of leaves.

Shot-hole disease of cherry and plum.

Spraying with Bordeaux mixture (3-3-50) or lime sulfur (1-40) combined with clean cultivation is said to be effective in controlling the shot-hole disease. The spray should be applied first when petals fall, followed by a later application in about two weeks. It is well to add about one pound of arsenate of lead powder to the spray to control chewing insects. This is also said to add to the effectiveness of the spray.

Brown-Rot (Sclerotinia cinerea) (22), (23)—This is not a common disease in Colorado. It is the same as the brown rot of peach and other stone fruits. See Peach.

CUCUMBER

Bacterial Wilt (Bacillus tracheiphilus)—Bacterial wilt is common in Colorado on cucumber, cantaloupe, squash and other cucurbits. The disease is characterized by a wilting of the leaves and runners. There is no indication of decay or other injury to the roots or stems. The wilting is caused by bacteria which gain entrance into the plant by means of the bites of insects. The bacteria once in the stem multiply rapidly and plug the water tubes thus causing the plant to wilt.

Since the disease is spread by biting insects the best way to control it is by spraying to control such common insects as the squash bug and cucumber beetle. Remove and burn affected plants at once.

Downy Mildew (Plasmopara cubensis)—Downy mildew affects not only the cucumber but all members of the cucumber family such as cantaloupes, watermelson, squash and pumpkins. Affected leaves show irregular yellow spots often covering an entire leaf in which case the leaf shrivels and dies. The oldest leaves are first affected, spreading towards the ends of the vine. A whitish downy fungus growth tinged with purple is often seen on the under side of the leaf. The few cucumbers formed are small and misshapen. Large numbers of spores are formed on the fungus growth, which serve to spread the disease.

Downy mildew may be held in check by spraying with Bordeaux mixture (5-5-50). The first application should be made as soon as the vines begin to run. Later applications should be given at ten day intervals.

Bacterial wilt of cucurbits on squash.

CURRANT

Cane blight of currants and gooseberries.

Canker (Nectria cinnabarina)—A very common disease in Colorado. The first evidence of the disease is a yellowing of the leaves and a premature coloring of the fruit. After the canes are dead, small round pink cushion-like spore masses are formed.

The spores usually enter the plant through wounds but after once gaining foothold it may spread rapidly causing much injury.

Avoid all unnecessary injury to the canes and cut out and burn all diseased canes as soon as they appear. Spraying is not recommended.

White-Pine Blister Rust—see Pine.

FLAX

Wilt (Fusarium lini) (60)—Wilt is common where ever flax is grown for two or more years in succession on the same soil. Affected plants turn brown, wilt and die as if from lack of water. Plants may be killed at any stage.

Flax wilt is due to a fungus that lives in the soil from year to year. The fungus penetrates the roots, grows into the water tubes poisoning the plant and cutting off its water supply. The fungus does not occur in new soil but is usually brought in on diseased seed. Since flax is being grown for the first time in many sections of the state it is extremely important that all seed be treated before planting. Use about one-half gallon of dilute formaldehyde, diluted at the rate of one pint to forty gallons of water, to each bushel of grain. Sprinkle the solution and stir the grain at the same time taking pains not to get the seed wet enough to stick together. Allow the seed to stand for several hours covered with canvas. Fan to remove light weight seed and diseased flax straw.

If the soil has once become infected the best procedure is to grow disease resistant strains of flax. Resistant strains may be developed

on the farm by selecting seed from the few plants that survive on a badly diseased field. Seed from such plants will show a remarkable degree of resistance. If this selection is continued for several years a highly resistant strain may be developed.

GOOSEBERRY

Mildew (Sphaerotheca mors-uvae) (61)—Mildew is the most serious disease of the gooseberry in Colorado.

Gooseberry mildew on fruit.

A whitish cobwebby growth appears on leaves, stems and fruit turning darker in color late in the season. In severe cases the fruit may be rendered worthless. During the early summer lots of small summer spores are formed on the white cobwebby growth, which aid in scattering the disease from plant to plant. In late summer small black spore cases are developed on the surface of affected parts. These contain spores which on account of the protection of the spore case serve to carry the fungus over winter.

Gooseberry mildew may be held in check by spraying with potassium sulphide, one ounce to two gallons of water. Apply first spray when the buds begin to open. Follow with additional applications at intervals of ten days or two weeks until fruit is ready to pick.

White-Pine Blister Rust—see Pine.

MILLET

Smuts (Ustilago crameri and U. panici-miliacei) (78)—Smut is the most important disease of millet in Colorado. There are two kinds of millet smut. The foxtail millets are affected by **U. crameri.** This fungus replaces the individual kernels with a black mass of

spores which is enclosed by the chaff of the grain. The Panicum millets are affected by **U. panici-miliacei,** which replaces the kernels with a black mass of spores but also destroys the chaff. The mass of spores is held together by a thin gray membrane.

Both of these smuts may be controlled by treating the seed with formaldehyde (1-40) in the usual manner for treating wheat.

Millet smut on foxtail millet. (Original in Colorado Experiment Station Bulletin 242, by Vasey.)

PEA

Powdery Mildew (Erysiphe polygoni) (62)—Powdery mildew is common in Colorado on both field and garden peas especially whenever grown late in the season. The usual white cobwebby growth characteristic of mildews is formed. This later turns dark due to the formation of numerous black spore cases large enough to be seen with the naked eye.

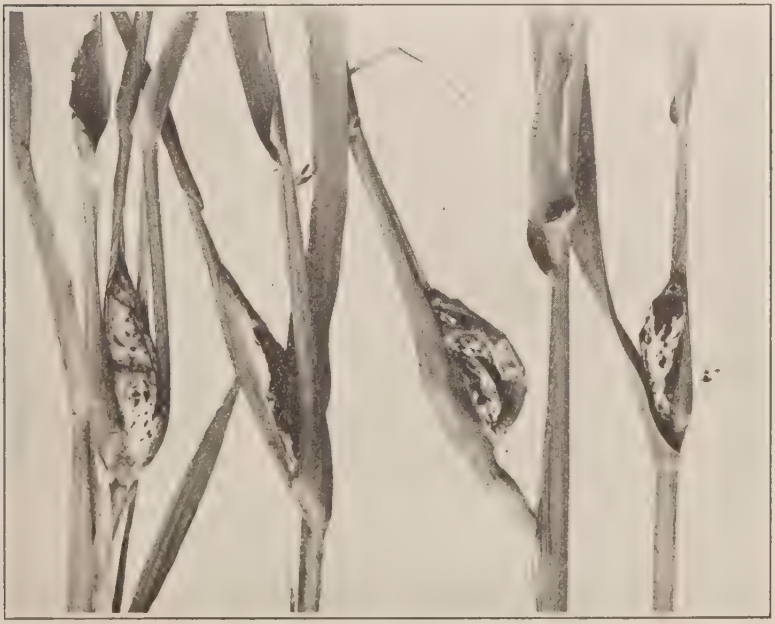
Spraying will control mildew but it is not practical. Plant peas as early in the season as possible and keep soil drained. Use seed from fields known to be free of the disease.

Stem Blight (Pseudomonas pisi) (63)—This is a bacterial disease affecting both field and garden peas. It first made its appearance in 1915 in the San Luis Valley and Northern Colorado where it caused much loss. Since 1919, however, the disease has not occurred in sufficient abundance to produce a great amount of injury.

Stem blight is characterized by a watery olive green to olive brown color of the stems and by yellowish and watery appearing leaflets.

The bacteria causing stem blight gain entrance to the plant through breathing pores or mechanical injuries. Avoid injuring the plant by harrowing or other means of cultivation.

Some varieties of peas are more resistant than others and if the disease again becomes abundant it would be well to select the most resistant kinds. Late planting is also said to reduce the amount of the disease.



Millet smut on proso millet. (Original in Colorado Experiment Station Bulletin 242, by Vasey.)

PEACH

Peach scab. (After Keitt.)

Scab (Cladosporium corpophilum) (64)—Scab is one of the worst diseases of the peach. It affects the fruit, twigs and leaves. It makes its first appearance about four weeks after the petals fall or shortly before the ripening period. On the fruit small round greenish brown spots are formed. These never extend very deep into the flesh. The small spots may run together and form irregular blotches. In severe cases the fruit is often cracked because the diseased skin does not expand to accommodate the growth of the fruit.

Scab may be controlled by spraying with self boiled lime sulfur (8-8-50). For early varieties only one spray is necessary. This should be applied one month after the petals fall. For later varieties two sprays are required, the second about three or four weeks after the first. The lime sulfur may be combined with arsenate sprays used to control insects.

Brown Rot (Sclerotinia cinerea) (22), (23)—Brown rot is perhaps the most destructive disease of the peach, but at present it is not known to occur in Colorado. Since it may be introduced at any time a description is given here.

Brown rot affects all stone fruits including plum, apricot, cherry, and almond. The greatest damage is done on the fruit although the blossoms and twigs may also be affected. On the fruit small brown spots are first formed, these rapidly enlarge until the entire peach is decayed. Whitish tufts of spores are soon formed over the

Brown rot of peach. (After Scott and Ayres.)

surface of the spots. These spores seem to spread the disease from place to place. Spores often fall on ripe fruit causing a decay after the fruit is packed and shipped. The fungus passes the winter in dead and decayed peaches often called "mummies." Hot moist weather is favorable to the development of the disease.

Brown rot may be controlled by spraying with self boiled lime-sulfur first about seven or eight weeks before the fruit is expected to ripen, and by making a second application about one month before the fruit is ripe.

Blight or Fruit-Spot (Coryneum beyerinckii) (24), (25).—This disease occurs in Colorado on peaches and apricots. The fruit leaves and stems are affected. Young buds on the fruiting wood are frequently killed. The green twigs are spotted and the young leaves and fruit drop. Injury is commonly accompanied by the formation of gum about the wounds. Gumming is very common in wet seasons. In badly infected orchards almost the entire crop of fruit may be destroyed. The fruit that survives in such cases is so badly spotted

that its market value is greatly lessened. On the leaves irregular reddish brown spots are formed which may fall out causing a shot-hole appearance.

Blight is caused by a fungus that grows in the tissues of the tender twigs, leaves and fruit. Spores are formed in the spots, which when blown about by wind, are means of spreading the disease. The fungus lives over the winter on infected twigs. Spores are produced until late in the fall. The most destructive infection takes place during the months of December and January when the fungus grows directly into the developing buds.

Blight may be controlled by spraying with Bordeaux (5-5-50) in the fall not later than December 15. A second application should be made in the early spring just before buds open.

Mildew (Sphareotheca pannosa) (65)—Mildew is a common disease of the peach in Colorado. The leaves, twigs and fruit are attacked. Irregular white powdery blotches are formed causing the leaves to curl and crinkle and the bark of the twigs to turn brown and dry. Similar white blotches are found on the fruit, checking its development and causing the flesh to become dry and hard.

To control mildew spray with lime sulfur solution or dust with flowers of sulfur. A close watch should be kept for the first appearance of the fungus, when the first application should be made. Later applications should be made at intervals of ten days or as often as necessary.

Powdery mildew of peach. (Original in Bulletin 107, by Whipple.)

PEAR

Fire Blight (Bacillus amylovorus) (4), (5), (6)—This is without doubt the most destructive disease of the pear and is very prevalent in Colorado. Fire blight also affects the apple and quince and sometimes the apricot and plum. Any part of the tree above ground may be affected. It becomes evident in the spring as soon as growth is started but seldom attracts attention until two or three weeks after the blossoming period. The twigs and fruit spurs shrivel, turn brown and then black, giving the appearance of having been burnt. Blight spreads down the twigs affecting the larger branches on which are produced dark sunken cankers. The entire tree is often killed. Fire blight is caused by bacteria which live in the growing soft tissues of affected plants. They are spread chiefly by insects and may enter the plant through insect bites or other wounds.

The bacteria live over the winter in affected tissues of the larger limbs. Such places are called "hold over" cankers. In the spring when the sap rises the bacteria become active and drops of clear sticky fluid flow from the cracks in the canker. These drops of ooze are full of bacteria which are scattered by insects and other agencies to healthy twigs.

Fire blight is a very difficult disease to control. It can be held in check by cutting out in the fall diseased branches which might be a source of infection the following spring. Cankers which occur in crotches should be scraped down to healthy wood and disinfected with corrosive sublimate. All blighted twigs should be pruned out and destroyed as soon as they appear in the spring. Such twigs should be cut several inches below the blackened tissues. The pruning knife should be disinfected between each operation by dipping into a solution of corrosive sublimate (1-1000).

Crown Gall—see Apple.

Rust—see Apple.

PINE

White Pine Blister Rust (Cronartium ribicola) (66)—This is an extremely destructive disease of all five-needle pines. It is a native of Europe but was introduced into this country a little over ten years ago. Since that time it has practically destroyed all the white pines of the Eastern states. It has been spreading slowly westward and a few years ago it was discovered in Western Minnesota. There

White pine blister rust. (After Stewart and Rankin.)

is great danger of its being introduced into the Rocky Mountain forests at any time. The United States Department of Agriculture is spending great sums of money in an effort to prevent its further spread. The native stands of the sugar pine and the Western White pine in the western forests are valued at $240,000,000 Both of these trees are known to be susceptible to the disease. If they once become infected there is little hope of controlling the disease unless it is discovered soon enough to eradicate it before it becomes wide spread.

The disease affects not only the five leaf pines but lives one stage of its life on the wild and cultivated currants and gooseberries. Upon pines in early summer the rust causes irregular swellings in the bark. On the swellings in early summer white blisters are formed which later break open to set free a dust-like mass of bright yellow spores. Affected trees are eventually girdled and completely killed.

The spores formed in the blisters on the pines are blown to currant and gooseberry bushes on the leaves of which they form, first, small yellow spots which also contains spores. These spores spread the disease to other currant or gooseberry bushes. In late summer and autumn a second kind of spore is formed on the currant or gooseberry leaves and are seen as a brown hairy coating on the lower surface of the leaves. These spores cannot infect the gooseberry or currant bushes but are scattered to the pine which they infect, starting the disease anew.

The only practical means of preventing loss from the white pine blister rust is to prevent its introduction into the Western states. Quarantine laws have been passed to prevent the westward shipment of any white pines, gooseberries or currants. Quarantine laws, how-

From Eleventh Annual Report, State Entomologist of Colorado

ever, are not always effective. Learn to recognize the disease if you see it and report all suspicious cases to the Agricultural College.

PLUM

Plum Pocket (Taphrina communis) (67)—This is a common and serious disease of the plum in Colorado. Affected fruits first turn yellow followed by a rapid enlargement to several times the normal size. The surface becomes wrinkled and the pit fails to develop being replaced by a large empty cavity. The diseased fruit later turns brown, shrivels and may fall off or remain attached to the tree for some time. The entire crop may be destroyed in this way.

Plum pocket is caused by a fungus which infects the young fruit as soon as it is formed causing it to make the abnormal growth described above. Where and in what condition the spores live over the winter is not definitely known, but it has been demonstrated that the disease can be controlled by spraying with lime sulfur. Either the factory or self boiled solution may be used. Only one application is necessary. It should be applied in late winter or in early spring before the flowers begin to open.

Shot-Hole—see Cherry.

Crown Gall—see Apple.

Black Knot—see Cherry.

POPLAR

Canker (Cytospora chrysosperma) (68)—Various species of poplar and willow are important in Colorado as shade and ornamental trees. In the more arid sections no other tree will make a satisfactory growth. Large numbers of these trees have been killed in the past few years by the canker disease. This is especially true in the southern half of the state.

Canker affects the twigs and large branches of the tree. The most prominent sign of the disease is the red gummy substance that is excreted over the surface of diseased branches in the form of slender thread-like coils or small red dots.

The disease is caused by a fungus that usually infects the plants through wounds of some sort.

Small branches are usually the first to die and the disease spreads rapidly from these down to the main trunk which is eventually girded, killing the entire tree. Shoots or suckers often put up from the ground after the upper part of the tree is killed.

Colored Plate on opposite page illustrates the poplar canker. Original used in Colorado State Entomologist's Annual Report for 1919.

To control the disease take good care of young trees by supplying sufficient moisture and avoiding mechanical injuries. If the tree is already infected it may often be saved by pruning out and destroying all diseased twigs and cankers, and painting over the wounds with shellac or coal tar.

Since the disease is known to occur in nurseries, all nursery stock should be inspected and any diseased stock destroyed.

POTATO

Fusarium Blight (Fusarium spp.) (69), (72)—Fusarium blight is common throughout Colorado, but is especially severe in the Greeley district. It is perhaps the most destructive disease of the potato in the state. It has been estimated that in 1917 there was a loss of 500,000 bushels in Colorado due to this disease.

The disease manifests itself first by a wilting and a rolling of the leaves followed in severe cases by a premature death of the remainder of the plant. On examination of diseased plants, the seed piece is found to be rotted and in later stages the roots and stem may also show signs of decay.

Fusarium blight is caused by fungus which lives in the soil and infects the seed piece and spreads from there into the stem and roots killing or seriously injuring the plant.

No thoroughly effective methods of control are known but the planting of whole potatoes for seed, combined with judicious irrigation and other cultural practices are perhaps the most effective measures. An excess of moisture should always be avoided. A long rotation raising other crops followed by alfalfa is also very beneficial.

Black Leg (Bacillus atrosepticus) (69), (70), (71), (72)—Black leg occurs in Colorado, but is not responsible for any great loss. The disease occurs on both vines and tubers causing an inky black discoloration near the ground line. The entire plant becomes yellow, wilts, and dies. The seed piece is nearly always rotted. New tubers may often become infected in the field and later develop a soft rot in storage.

Black-leg is caused by bacteria that live from year to year in partly rotted tubers. The organism probably does not live in the soil for a very long time.

A seed piece showing any signs of decay should never be planted. During the growing season all diseased plants should be pulled up

and destroyed. All seed should be treated with either formaldehyde or corrosive sublimate as described in Part III.

Dry Stem Rot (Rhizoctonia solani) (69), (70), (72)—This disease, sometimes spoken of as "Rhizoctonia," is often very injurious to the potato. Both tubers and vines are affected. Diseased plants first show a rolling of the leaves with no pronounced wilting. Small aerial tubers may be produced on the stems above ground. Dry reddish brown to black scabs are produced on the tubers.

Rhizoctonia of potato on tubers. (Original in Bulletin 70, by Rolfs.)

The disease is caused by a common soil fungus and for this reason is difficult to control. The black scabs mentioned above are masses of the fungus and plants from tubers so affected are always seriously injured. See selection, seed treatment with corrosive sublimate, and crop rotation will decrease the amount of the disease.

Scab (Actinomyces scabies) (69), (70), (72), (73)—Scab is common throughout Colorado. Rough, corky, brownish patches are formed over the surface of affected tubers, and the value of the crop is reduced. Scab is caused by a fungus that lives from year to year in the soil or on diseased tubers.

Badly scabbed potatoes should never be used for seed and all seed should be disinfected with either formaldehyde or corrosive sublimate. Alkalinity of the soil increases the amount of scab while acidity decreases it. The addition of wood ashes, lime, and fresh barnyard manure tends to increase the injury from the scab, while plowing under green manure tends to decrease it.

Potato Wart (Chrysophlyctis endobiotica) (74), (75), (76)—Wart is a destructive disease of the potato which was discovered in this country for the first time in 1918. It has long been known as one of the most destructive diseases of the potatoes in Europe. So far it has not been found in Colorado. A close watch should be kept for its appearance in Colorado and any suspected tubers should be sent to

the Plant Pathologist, Colorado Agricultural College, Fort Collins, Colorado.

Rough spongy warts are produced on affected tubers. The warts are light brown at first but become black with age. Often all

Rhizoctonia of potato, on stems. (Original in Bulletin 70, by Rolfs.)

Aerial tubers and "little potatoes" formed as a result of infection by Rhizoctonia. (Original in Bulletin 70, by Rolfs.)

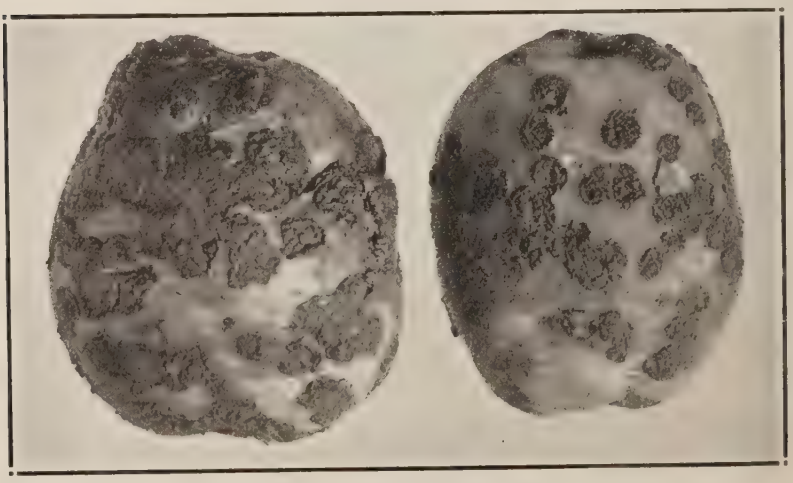
potatoes in a hill are worthless. The disease does not affect the plant above the ground.

The fungus causing potato wart lives from year to year in the soil or on diseased tubers. Crop rotation and the use of resistant varieties offer the best methods of control after the disease has become established.

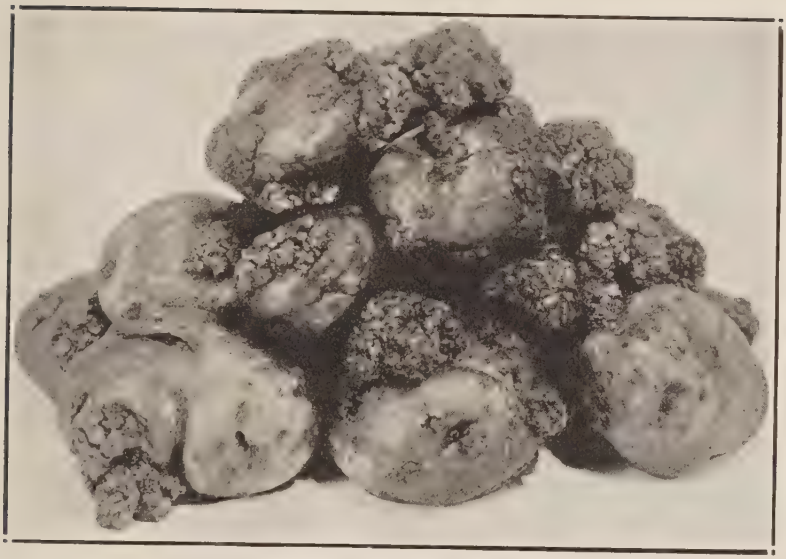
Early Blight (Alternaria solani) (77), (70)—Early blight is a leaf spot disease that is often very prevalent in Colorado. Roundish brown spots marked with concentric rings are produced on affected leaves. The disease seldom causes great loss, but in severe cases some injury is produced. The disease is more severe in moist localities. Early blight may be controlled by spraying with Bordeaux mixture (5-5-50). Spraying should begin early before the blight becomes serious.

Tip-Burn (Hopper-Burn) (70)—This disease which is characterized by a browning and burning of the tip and margins of the leaves is common in Colorado. For many years it was thought to be a physiological disease caused by unfavorable moisture relations. Recent work, however, indicates that an insect, the potato leaf hopper, is largely responsible for the trouble. Probably both factors are involved.

Spraying to control the leaf hopper should reduce the amount of the disease.



Potato scab. (After Stakman and Tolaas.)



Potato wart. (Photograph, courtesy of Plant Disease Survey.)

Early blight of potato.

Hopper burn of potato.

RASPBERRY

Anthracnose (Plectodiscella veneta) (79)—This disease occurs also on the blackberry but is more destructive on the raspberry. It is not of great importance in Colorado. Both leaves and the canes are affected, although the greatest injury is to the canes. At first small purplish spots are produced which later increase in size and become grayish white in the center. The margins of the spots may run together and girdle the cane. Affected canes often crack badly. The spots formed on the leaves are similar to those on the canes except that they are smaller. The dead tissue often drops out, giving the leaves a shot-hole effect. Fruit and pedicels may also be attacked.

Diseased canes should be eradicated before the spring season. Clean, healthy plants should be set. Short rotations should be practiced. Spray with Bordeaux mixture (4-4-50) as follows: (1) before the leaves appear, (2) after the leaves are well formed and when the shoots are about six inches high, (3) just before the blossoms appear. If necessary later sprays may be applied at ten day intervals.

Spur-Blight (Mycosphaerella rubina) (69)—In some years this is a serious disease of the raspberry in Colorado. It reduces the crop by reducing the number of fruit spurs and killing the buds. Diseased canes are extremely brittle and break easily when being put down in the fall or taken up in the spring.

The first symptoms are seen about the first of July. Chocolate brown spots are formed over the lower nodes of the canes and often also along the internodes and on the leaf petioles. The buds from the lower nodes are either killed outright or are so weakened that only poor shoots are produced. No fruit is developed on the lower half of the canes.

Spur-blight may be controlled by spraying with Bordeaux mixture (3-3-50) with two pounds of resin-fish-oil soap added as a sticker. The spray should be applied to the young canes and not to the fruiting canes. Spray (1) about the first of June when the canes are 8-12 inches high, (2) two weeks later, (3) two weeks after the second spray. Remove and burn all old fruiting canes as soon as the berries have been gathered.

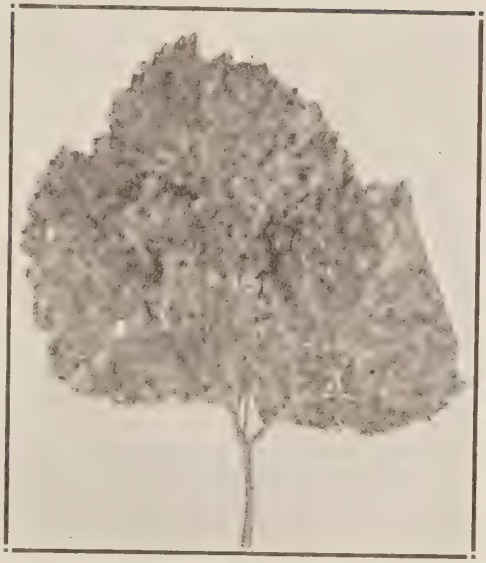
Leaf-Spot (Septoria rubi)—Leaf-Spot occurs on raspberries,

The Colored Plate on the opposite page illustrates the spur-blight. Originally used in Bulletin 206, by Sackett.

COLORADO AGRL. EXPT. STA.

blackberries and dewberries being perhaps more severe on the latter. The spots appear about the middle of June as small brown areas. They may become so numerous that an affected leaf will dry up and die.

Leaf-spot may be controlled by spraying with either Bordeaux mixture (4-5-50) or lime sulfur (1-50). The first application should be made just after the buds unfold and be followed by later applications at intervals of two or three weeks until the fruit is two-thirds matured.



Leaf spot of dewberry.

STRAWBERRY

Leaf-Spot (Mycosphaerella fragariae)– This is the most common strawberry disease. Usually no great injury results from leaf-spot but the loss in certain instances has been very high.

Leaf spot of strawberry.

The spots at first are small red or purple dots which rapidly increase in size, becoming whitish gray in the center. The margins remain purple.

Remove and destroy diseased leaves before set-

ting or use healthy plants. Spray with Bordeaux mixture (4-4-50) before the blossoms open. In case of severe infection mow and burn over the patch just after harvesting. A new set of leaves will be formed free of the disease.

TOMATO

Blight (Fusarium lycopersici) (82), (83)—The first indications of blight is a yellowing of the lower leaves followed by wilting and dying. After a period of time which varies with the weather and the severity of the attack, the entire plant may wilt and die. The woody portions of affected stems are browned. This can easily be detected by pulling off the larger leaves and noting the brownish dots on the leaf scar.

The disease is caused by a fungus that lives from year to year in the soil. Spraying is of no avail. Crop rotation and the use of resistant varieties are the only means of control.

Blossom-End Rot (84), (85)—This is a non-parasitic disease due probably to improper moisture relations. Decay starts usually on half grown tomatoes as a slightly sunken black spot which spreads rapidly until the entire fruit is destroyed.

Spraying has no effect on blossom-end rot. Since dry soil conditions seem to favor the development of the disease, an abundant regular supply of moisture should be maintained.

PART III

PLANT DISEASE CONTROL

General Principles of Control

Every measure that is recommended for the control of a plant disease is based upon a knowledge of the factors which produce it. Every plant disease has a cause. The logical way to control a plant disease is to destroy the cause. If the disease is produced by unfavorable conditions of environment the environment should be modified to suit the needs of the plant. If it is caused by a parasitic organism the organism should be destroyed, or else the plant should be protected against its attack.

A knowledge of the life history of the organism is necessary in order that the measure for destroying the organism or protecting the plant may be applied at the proper time. The conditions which favor the development and spread of the organism should also be known in order that these conditions may be avoided.

In addition to the above, one should be able to recognize a disease in all its stages. It is especially important to be able to detect a disease in its early stages of development in order that control measures may be applied in time to be effective. Many diseases are localized in their distribution but they are constantly spreading to new areas. Too often diseases invade new territory and are not discovered until they become so strongly established that control measures are difficult. One should be able to recognize not only the diseases that are already present, but also those which are liable to be introduced at any time.

All plant disease control measures may be divided into four classes; (1) those based upon the exclusion of a disease from a given area, (2) those which depend upon the eradication of a disease producing organisms in a given area, (3) those involving the protection of plants against a disease producing agent and (4) those based upon the use of disease resistant plants.

Exclusion

Many of the most injurious plant diseases occur only in restricted areas. There are diseases common in Europe which do not occur in this country, and the diseases common in this country do not occur abroad. With the development of commerce and travel, however,

these diseases are constantly spreading to new areas and gradually increasing their range.

Within the past eighteen months three new and serious plant diseases have been brought into this country from abroad; namely, the Black Wart of Potato, Flag Smut of Wheat, and Take-All of Wheat, Oats, Barley, and Rye. The White Pine Blister Rust, which has destroyed the White Pine forests of the Eastern States, was brought into this country from abroad. The same is true of the Chestnut Bark Disease which has caused enormous losses in the New England and Middle Atlantic States.

Even in the United States many of our worst diseases occur only in certain sections. Many of the most serious plant diseases have not yet made their appearance in Colorado. There are, however, more diseases in the state at the present time than there were ten, fifteen, or twenty years ago and new ones can be expected to show up in the next few years.

Federal and State quarantines are important means of excluding injurious plant diseases. All nursery stock, seeds and bulbs, that are liable to be infested with injurious parasites are carefully inspected by the government inspectors and if found infested are destroyed. Quarantines are, however, not always effective and every now and then a disease makes its appearance in a new section of the country. For this reason every grower should be on the constant look out for the first appearance of a disease in a new area. The early discovery and immediate suppression of a disease that has just been introduced may mean the saving of thousands of dollars to a community.

Diseases may be brought into a new locality or introduced into clean soil by planting of diseased seeds or seeds that carry the disease on their surface. The planting of seed of unknown origin should be avoided. Any seed that is likely to carry spores of disease producing organisms should be disinfected before planting.

Eradication

Disease control by eradication measures consists of the complete destruction of a disease producing organism in a given area. Eradication measures are most applicable when exclusion measures have failed and a new disease has been discovered before becoming widespread. Eradication methods are best carried out by the State or Government. The Federal and State Governments have united in an effort to eradicate Potato Wart, Flag Smut of Wheat, and Take-

All of Cereals in this country. The White Pine Blister Rust made its appearance in a small isolated area in Northern Minnesota a few years ago. Intensive efforts are now being made to eradicate the disease in that area. The Barberry Eradication Campaign being carried on by the U. S. Department of Agriculture is a good example of eradication on a large scale. Eradication methods may also be used on a small scale in eradicating diseases that have gained entrance into such places as greenhouses, hot beds, etc. Soil sterilization by steam or formaldehyde are the processes usually employed.

Protection

The old adage that "an ounce of prevention is worth a pound of cure," is extremely applicable to plant diseases. Few plants that have once become affected with a disease can be cured by treatment as is the case with men and animals. Plants must be protected from infection by disease producing organisms.

The most practical plant disease control measures come under this head. The common means of protecting plants from the attacks of parasitic organisms are as follows: (1) Good cultural practices, (2) Crop sanitation, (3) Crop rotation, (4) Seed selection and seed treatment, and (5) Spraying.

Good Cultural Practices

There are a large number of disease-producing organisms which can attack plants only when they are in a weak condition. Since proper cultural methods tend to produce healthy, vigorous plants this alone in some cases is adequate protection from the disease. Moreover, certain physiological diseases are produced as a direct result of improper cultural methods. Better cultural practices would, of course, protect the plant against these troubles.

Crop Sanitation

Since most parasitic diseases are spread by the scattering of the causal organism from a diseased to a healthy plant, the removal and destruction of diseased plants or parts of plants is a very important means of protecting the healthy plants. The practicability of this method is, of course, determined by the nature of the disease to be controlled.

Crop Rotation

Many disease-producing organisms live from year to year in the soil but only become sufficiently plentiful to injure the crop when the plant is grown for several years in succession on the same soil.

If a system of rotation is adopted in which the susceptible crop is grown on the same soil not oftener than once in three or four years the organism will die out or at least will not develop in sufficient quantities to seriously injure the crop. There are a number of diseases such as wilts and root rots that can be held in check only by this method. Moreover, a number of disease-producing organisms normally live over the winter on diseased parts of plants that are left scattered over the field. If the crop is planted on the same soil two or more years in succession this diseased rubbish and plant parts will be in the best possible place for starting the disease the second year. Crop rotation involves almost no expense other than a little forethought and planning. The returns in the disease free crops pay for this trouble many times over, not to speak of the added gain in soil fertility.

Seed Selection and Seed Treatment

Selection of clean seed and seed disinfection not only prevent the introduction of disease-producing organisms to new localities but they also act as a protection to the resulting crop. The spores of many parasitic fungi are carried over on the seed and infect the young plant when it begins to grow. Disinfection with certain solutions of proper strength will kill the fungus spores without injuring the seed and the plants produced from such seed are usually free of disease. Solutions of formaldehyde, copper sulfate or corrosive sublimate are commonly used for this purpose. There are other disease-producing organisms however which infect the developing seed and live over inside the tissues of the seed. Ordinary methods of seed disinfection will not kill the organism within the tissues without injuring the seed. For these diseases, therefore, the selection of disease-free seed is the most effective means of control. Seed should be selected in the field from disease free plants because diseased seed often cannot be detected after harvest.

Spraying

This is one of the most common methods of plant disease control. The object of spraying is to keep the surface of the plant covered with a substance that will kill any spores that fall upon it and at the same time will not injure the plant. The spraying must be applied before the spores appear, for, if the spores once gain entrance into the plant, spraying is useless. Spraying should be done before rains and not afterwards, because spores require water for germination and it is at this time that protection is needed. Sprays,

when properly made and applied, will not wash off in an average rain, so there should be no worry from this cause.

Bordeaux mixture and lime-sulfur are the two most important sprays used for controlling fungous diseases. Chemicals used for this purpose are commonly called fungicides. Recently, considerable attention has been given to the application of fungicides in the form of powder. This method, although it promises to be of much value, is yet in the experimental stage.

The efficiency of spraying and seed treatment depend largely upon proper preparation of the solution employed. A spray improperly made may not only fail to protect the plant from infection but it may also seriously injure fruit or foliage. Solutions used in seed treatment inaccurately prepared or wrongly used may either fail to kill the fungous spores or it may injure the germination powers of the seed or both. The greatest care should be taken in following directions for mixing and applying both sprays and seed-treatment solutions.

Use of Disease-Resistant Plants

There are a number of varieties of crop plants which on account of some inherent quality are resistant to certain plant diseases. It is obvious that the use of such varieties offers an excellent means of disease control provided the variety is otherwise desirable. Moreover, in the case of many diseases, methods of exclusion, eradication, and protection are ineffective or else impractical. In such cases the use of disease-resistant varieties offers the only means of control. The use of disease-resistant plants not only offers a means of control when other methods fail but whenever such varieties can be obtained it is by far the most effective and inexpensive method.

Disease-resistant varieties have been used with success in combatting a number of serious diseases but so little is known about the true nature of disease-resistance that the work of producing disease-resistant plants has progressed rather slowly. Often existing varieties may show a high degree of resistance to certain diseases but at the same time lack other characters necessary to make it a profitable commercial variety. Such resistant varieties may also not be adapted to the particular region in which the disease is most destructive. In such cases resistant varieties possessing the desirable commercial characteristics have been produced by crossing with other varieties.

It has been possible in certain cases to produce disease-resistant

varieties from any given variety by selecting resistant individuals from heavily diseased fields. It was by this method that wilt-resistant flax, blight-resistant tomatoes, and varieties of cabbage resistant to yellows were produced.

The production of disease-resistant plants is a slow, difficult and expensive task and is one that must, for the most part, be left to the Experimental Stations.

PREPARATION AND APPLICATION OF SPRAYS AND OTHER FUNGICIDES

Bordeaux Mixture

This is one of the oldest and best known fungicides. It is perhaps the most valuable spray known for the control of plant diseases. Bordeaux mixture is prepared by mixing a solution of copper-sulfate (blue vitriol) with a solution of stone lime slaked in water. For example, Bordeaux mixture (4-5-50) means that 4 pounds of copper-sulfate and 5 pounds of lime are used to 50 gallons of water. The quality of Bordeaux mixture depends greatly upon the manner in which it is prepared. Bordeaux mixture improperly prepared is worthless. The copper-sulfate and the lime must be dissolved separately and mixed just before using. After the two solutions are mixed they should be used at once, as Bordeaux mixture loses its strength in a very short time. Stock solutions may be prepared by dissolving each ingredient in a small quantity of water. These solutions should be diluted to the proper strength and mixed when ready for use. The following directions may serve as a guide for the preparation of 50 gallons of (4-5-50) Bordeaux mixture.

The quantities of material may vary with the strength and quantity of solution desired.

Materials:

Copper-sulfate (bluestone)	4 pounds
Stone lime	5 pounds
Water	50 gallons

Apparatus:

2 half-barrel tubs with capacity of about 30 gallons, made by sawing a 60-gallon barrel through the middle.
1 60-gallon mixing barrel.
2 or more wooden pails.
1 strong paddle about 6 feet long for stirring the mixture.
1 pair of hand scales for weighing materials.
1 strainer of cloth or 20-mesh brass gauze.

Preparation:

1. Dissolve 4 pounds of copper-sulfate in 25 gallons of water by suspending the copper sulfate in a cloth bag in such a way that the bag will be just under the surface of the water in one of the 30-gallon tubs.
2. Slake 5 pounds of stone lime in the other tub and add water to make 25 gallons.
3. When the solutions are thoroughly dissolved they should be mixed by having one man dip up a pail of copper-sulfate solution and pour it into the 60-gallon barrel, through a cloth suspended over the top, at the same time that another man is pouring in a pail of the lime solution. This process should be continued until the amount of spray desired is mixed. Remove the cloth from the top of the barrel and stir vigorously.
4. Strain the mixture again when filling the spray tank. Use as soon as mixed.

Making Bordeaux mixture. (Original in Bulletin 206, by Sackett.)

Stock Solution of Bordeaux Mixture

When spraying is to be done on a large scale it may be advisable to make stock solutions of the copper-sulfate and lime. Stock solutions are made as follows:

1. Dissolve the required amount of copper-sulfate in water at the rate of 1 pound to 1 gallon. The bluestone should be suspended in a cloth sack beneath the surface of the water where it will dissolve in a few hours.
2. Slake the required amount of stone lime and add water enough to make one gallon to each pound of lime.

These solutions will keep indefinitely. They should be kept in closed containers to prevent loss of water by evaporation. To make Bordeaux mixture from stock solutions dilute to the necessary strength and mix in the usual way. For example (4-5-50) Bordeaux mixture is prepared from stock solutions as follows:

1. Stir stock solution thoroughly.
2. Dilute 4 gallons of stock solution of copper sulfate to make 25 gallons.
3. Dilute 5 gallons of stock solution of lime to make 25 gallons.
4. Mix these two solutions in the manner given above.

Precaution—Only wooden or earthen vessels should be used to contain the copper-sulfate solution or the Bordeaux mixture for they will corrode metal.

Bordeaux Mixture and Resin-Fish-Oil Soap

In spraying Asparagus and other plants with a glossy foliage it is often necessary to add a substance known as a "sticker" in order that the spray adheres. This is accomplished by adding resin-fish-oil soap to ordinary Bordeaux mixture.

1. Dissolve 2 pounds of resin-fish-oil soap in 2 gallons of water.
2. After the copper-sulfate and lime solution have been mixed, add 2 gallons of soap solution to 50 gallons of Bordeaux mixture.

Self-Boiled Lime Sulfur

Some plants, especially stone fruits, are extremely susceptible to injury from Bordeaux spray. For spraying such plants self-boiled lime-sulfur is often used. This spray is prepared as follows:

1. Weigh out 32 pounds of lime and 32 pounds of sulfur. The sulfur should be thoroughly sifted.
2. Place the lime in a barrel and add about 4 gallons of water.
3. Add sulfur as soon as the lime begins to slake. Stir vigorously, adding enough water to make the mixture pasty.

4. Cover the barrel to retain the heat and let stand for five to ten minutes.
5. Add at least 25 gallons of cold water with vigorous stirring as soon as the lime is thoroughly slaked. It is important to cool the preparation as soon as the lime is completely slaked.
6. Dilute to 20 gallons or keep as a stock solution and dilute in proportions as needed.
7. Strain through a cloth or 20-mesh wire gauze before putting into the spray tank.

Both lime-sulfur and Bordeaux mixture as well as any other spray should be applied with a good pressure spray pump. A nozzle that will break the spray into a fine mist is necessary. Good spray pumps of many sizes and types can be bought on the market to suit the purpose of any grower.

Commercial Lime-Sulfur

Commercial lime-sulfur is another valuable fungicide, especially as a dormant spray. This spray differs from the self-boiled lime sulfur in that it is boiled over a fire instead of by the heat of the slacking lime. It usually is prepared in the factories in concentrated solutions. Buy the concentrated mixture and dilute according to directions supplied by the manufacturers.

Ammoniacal Copper Carbonate

This is a spray that is often used late in the season when it is desired not to spot the fruit or foliage with Bordeaux mixture. The spray is prepared as follows:

1. Add enough water to 5 ounces of copper carbonate to make a thin paste.
2. Dissolve the paste in three pints of ammonia diluted with 2 gallons of water.
3. Add water to make 45 gallons.

Flowers of Sulfur

The application of flowers of sulfur is recommended for the control of many diseases, especially the powdery mildews. The sulfur is applied in the form of fine dust. It may be applied on a small scale by dusting from a pepper box, but when applied extensively a special form of bellow-blowers should be used.

Formaldehyde

This fungicide is used chiefly for seed disinfection. The solution can be purchased in strengths approximating 40%. One pint of

40% formaldehyde diluted to 40 gallons is the usual formula although in special cases different proportions are used. The length of the treatment varies with the seed treated. Use as directed for the particular disease and crop.

There are three standard methods of treating grain with formaldehyde. Twenty years of use have shown these to be efficient and reliable. These are: (1) The soaking method, (2) The open tank method, and (3) The sprinkling method. Directions for the use of each of these methods are given below. Select the method best adapted to your conditions and equipment and then follow the directions carefully.

THE SOAKING METHOD

1. Estimate the amount of seed to be treated and purchase formaldehyde (40 per cent strength) one pint for 40 bushels of grain.
2. Clean the seed thoroughly by fanning so as to remove all unbroken smut balls.
3. Dilute the formaldehyde at the rate of one pint to 40 gallons of water.
4. Put a sufficient amount of the diluted solution into a barrel or tank to immerse one or more sacks of seed.
5. Put seed in gunny sacks and immerse in solution. Do not fill the sacks too full; allow room for agitation of the grain so that each seed will become thoroughly wet.
6. Leave the seed in the solution length of time specified in Table I.
7. Remove the sacks and drain, allowing the excess solution to run back into the barrel or tank. Replenish the solution when it gets too low.
8. Leave the treated grain in the wet sacks for not less than six hours nor more than 12 hours. Place the sacks where they will drain rapidly.
9. Plant immediately or empty the grain and spread out in a thin layer to dry. Drying may be facilitated by frequent shoveling.

THE OPEN TANK METHOD

1. Make the formaldehyde solution the same as for the soaking method.
2. Pour the loose grain slowly into the solution in an open vessel. Stir thoroughly and skim off the smut balls.
3. Soak for length of time specified in Table I.
4. Remove the grain, pile, and cover with wet sacks or canvas for not less than six hours and no more than 12 hours.

THE SPRINKLING METHOD

1. Clean the seed thoroughly by fanning so as to remove all unbroken smut balls.

2. Use a clean floor, wagon-bed, or canvas in the open.

3. Spread out a few bushels of grain. Make the formaldehyde solution the same as for the soaking method, and sprinkle it over the grain as it is being shoveled around.

4. Sprinkle at the rate of one gallon of diluted formaldehyde solution to one bushel of grain. A garden sprinkling can may well be used.

5. After all the grain is treated, pile and cover with disinfected sacking or canvas for from 6 to 12 hours.

TABLE I

Use Formaldehyde of Commercial 40 Percent Strength

Grain	Kind of Smut	Proportion of Formaldehyde to Water Mixed	How Long to Soak in Solution
Wheat	Bunt of Stinking Smut	1 pt. to 40 gals.	10-20 minutes
Barley	Closed-Hidden	1 pt. to 40 gals.	10-20 minutes
Oats	All kinds	1 pt. to 40 gals.	10-15 minutes
Millet	All kinds	1 pt. to 40 gals.	40-60 minutes
Rye	Stem Smut	1 pt. to 40 gals.	10-15 minutes
Emmer	Closed	1 pt. to 40 gals.	10-20 minutes
Sorghum	Kernel	1 pt. to 40 gals.	2-4 hours

PRECAUTIONS

Follow directions carefully. Failure to do this may result in the treatment proving ineffective.

Never put treated grain in sacks, barrels, or seeders which have contained untreated seed until they have been disinfected with the formaldehyde solution.

Treated grain may be kept indefinitely if thoroughly dried and protected from further contamination.

If treatment is performed during the winter, care should be taken not to expose the wet grain to frost, as it may result in injury to germination.

All grain should be thoroughly fanned before treating by the soaking or sprinkling methods. If you have not a fanning mill you should use the open tank treatment.

Corn smut, and loose smut of wheat and barley, are not controlled by the above treatments.

Do not use copper sulfate treatment for oats.

When purchasing formaldehyde, look for the standard red label bearing the recommendation of the Colorado Agricultural College. This label furnishes complete directions for seed treatment.

FORMALDEHYDE TREATMENT FOR SEED POTATOES

Soak the seed tubers in formaldehyde solution (1 pint to 30 gallons) for two hours. Either metal or wooden containers may be used. The same solution may be used several times provided it is not left uncovered for any length of time. Pour off the solution and permit the tubers to dry. All containers used to handle the seed after treatment should first be disinfected with the formaldehyde solution. The tubers should be treated before cutting unless they are to be planted immediately. Potatoes treated with formaldehyde may safely be fed to stock if thoroughly washed.

CORROSIVE SUBLIMATE (Poison)

This is a fungicide used chiefly for disinfection of seed potatoes. Four ounces of corrosive sublimate to 30 gallons of water is the usual formula. Dissolve the corrosive sublimate in a gallon or two of hot water and then dilute to 30 gallons. Soak the tubers in this solution for one and one-half hours. Metal containers should never be used. Corrosive sublimate is a violent poison and should be carefully handled. Potatoes treated with this solution should not be fed to stock.

HOT WATER TREATMENT FOR CONTROL OF LOOSE SMUTS OF WHEAT AND BARLEY

Apparatus

1. One accurate and reliable thermometer.
2. Three large barrels, tanks or vats.
3. Several good strong gunny sacks (not canvas).
4. One large boiler in which to heat water.
5. One sprinkling can.

Procedure

1. Heat water in boiler to almost boiling temperature. Pour this into one of the large barrels, tanks or vats and refill boiler. Add cold water and stir with vigor until the temperature is exactly 86 degrees F.

2. Fill the gunny sacks about three-fourths full of grain and tie loosely. Immerse the sacks in the water at 86 degrees F., move up and down several times to expel the air and leave immersed for four hours.

3. After four hours, pour into the second barrel or vat a quantity of nearly boiling water and cool it down by slowly adding cold water with constant stirring until the temperature is exactly 112 degrees F. Refill the heating boiler. Immerse the grain that has

been soaking for four hours into this one, move up and down several times and keep immersed for 15 to 20 minutes.

4. In the meantime, the third barrel should be prepared in a similar manner with water at exactly 129 degrees F. When the grain has been in the second barrel for 15 or 20 minutes remove and place in this barrel with water at 129 degrees F. The temperature of the water will be lowered when the grain is put in. If it falls below 122 degrees F., add a little water from a sprinkling can. The grain should remain in this barrel exactly ten minutes and the water should be kept between 124 degrees F. and 127 degrees F. It should never rise above 129 degrees F.

5. After ten minutes take the bags out and drain them thoroughly. Spread the grain out in a thin layer and allow to dry. The drying process may be speeded up by frequent shoveling over or stirring with a wooden rake. The grain may be planted as soon as dry enough to run freely thru the drill. If it is planted before it is thoroughly dry, the increase in weight from the water absorbed must be compensated for by planting a little more than the usual amount per acre. Care should be taken not to expose the grain to freezing temperature while still wet.

The above treatment when properly carried out will effectively control not only the loose smuts of wheat and barley, but any of the smuts affecting the small grains. On account of the difficulty in applying the treatment it is recommended that only a small lot of grain be treated and that this be planted in a small seed plot isolated as far as possible from other grain fields. The seed produced on such a seed plot should produce plants free of smut.

SALTING METHOD FOR REMOVING ERGOT BODIES FROM RYE

Make a 20 per cent brine solution by dissolving 40 pounds of common salt in 25 gallons of water. Mix the solution in a large barrel, tub or other suitable container. Pour the rye to be cleaned slowly into this solution while another person stirs vigorously. The sound rye kernels will sink to the bottom while the light kernels and ergot bodies will float on the surface. Skim off the ergot bodies and light kernels.

As the specific gravity of grain at different stages of dryness varies slightly, different lots of grain will require different strengths of solution. If the ergot bodies do not float readily, add more salt

to the solution. If the sound kernels float, add more water. When all the ergot has been removed, drain off the brine and rinse the grain with fresh water to remove the salt. (If the grain is not rinsed the salt adhering to the seed will injure it during germination.) Spread the cleaned grain on a clean floor and allow to dry. It is then ready for planting.

Since the ergot bodies lose their vitality when grain is stored over winter, this treatment is necessary for seed grain only when it is to be planted the fall after harvest. If the grain is to be used for feeding purposes, however, the ergot must all be removed because it contains a very potent poison.

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APPENDIX

Directions for sending in plant disease specimens for identifications:—During the growing season numerous specimens of plant diseases are mailed to the Agricultural College for identification, accompanied by a request for advice on methods of control. The College is willing and glad to render service along this line and in order that the most accurate and reliable information can be supplied we ask that certain important suggestions be carried out in preparing the specimens for mailing. Frequently specimens are received at the College in such poor condition that it is almost impossible to make an accurate determination. If the plant is sufficiently small it is well to include roots, stems, leaves, and fruit when possible as very often one part of a plant may die as a result of an infection on some other part. For example the leaves and fruit may die as a result of an organism attacking the roots or stems. In such cases if only the leaves and fruit were sent it would be impossible to determine the cause of the injury.

Many of the specimens received at the College in poor condition were no doubt in good condition when mailed but it must be remembered that such mail is often on the road two or three days during which time the specimens become dry and brittle before reaching their destination.

Specimens should be wrapped in several thicknesses of moistened newspaper, then covered with several layers of thick wrapping paper or inclosed in a pasteboard box.

Address all specimens to,

The Colorado Experiment Station
State Agricultural College,
Ft. Collins, Colorado.

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